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HOUSE BAT MANAGEMENT

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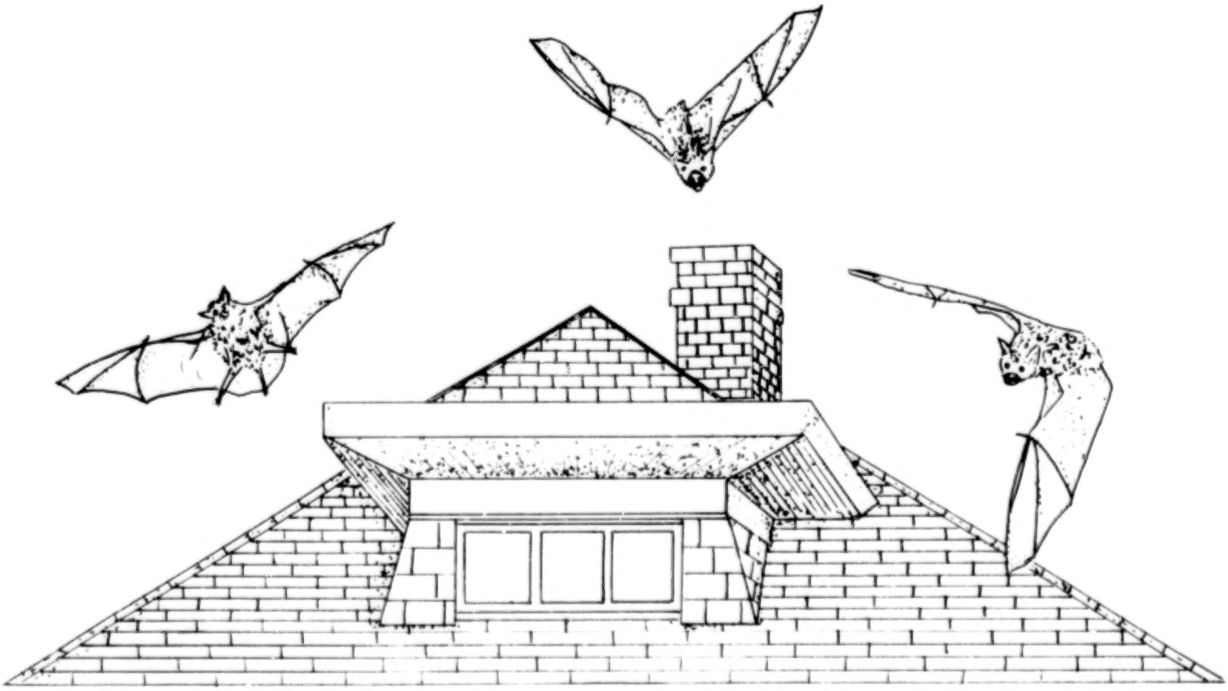

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HOUSE BAT MANAGEMENT

By Arthur M. Greenhall

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Foreword

The United States Fish and Wildlife Service, Department of the Interior, has responsibility for protection and management of bats to alleviate conflicts with man. A major obstacle to effective house bat management has been the lack of a single source of background information and sound recommendations for solutions to the different problems that sometimes arise when humans and bats interact. This publication provides a compendium of facts and techniques to respond to this problem and to guide future bat management activities.

In "House Bat Management," emphasis has been placed on nonlethal control as preferable to lethal control. Chemical toxicants do not solve the problems but often create worse ones. Recommended management methods should be selective for the offending bats, should not be hazardous to human beings or the environment, and should have no long-term harmful effects on bat populations. The objective should be exclusion. The batproofing techniques described herein provide numerous acceptable alternatives to lethal poisons and chemicals for dealing with bat problems and hazards.

Recent declines in bat populations throughout North America and greater appreciation of their ecological roles have contributed to the need for sound management policies and strategies essential for bat conservation. Future research needs have also been identified to build upon the base of knowledge reviewed in this manual.

"House Bat Management" should be useful to homeowners, wildlife biologists and managers, public health officials, physicians, veterinarians, conservationists, architects, building contractors, urban planners, and others interested in or concerned about bat interactions with humans.

David L. Trauger, Chief
Division of Wildlife Ecology Research

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House Bat Management

by

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Abstract

The soundest long-term solution for the management of bats that enter buildings and cause a nuisance problem or present a public health hazard is by batproofing the structure. Chemical toxicants do not solve house bat problems and may create worse ones. This manual describes batproofing techniques that will provide effective and acceptable alternatives for dealing with house bat problems and hazards. Recent declines in bat populations and greater appreciation of the ecological importance of bats have identified the need for sound management strategies that will encourage bat conservation while protecting human health and solving nuisance problems. One of the best deterrents against house bats is to improve the energy efficiency of the structure since bats may enter holes through which heat is lost. Heat conservation methods used for batproofing will also be eligible for Federal residential energy tax credits. The manual should be useful to homeowners, public health officials, physicians, veterinarians, conservationists, and others interested or concerned about bat interactions with humans.

Throughout history bats have aroused the curiosity and interest of men. Bats of the United States feed primarily upon insects, many noxious. Natural bat roosts are caves and tree hollows. A few species have readily taken their abode in houses thus gaining for themselves the name of "house bats" (Allen 1962).

Bats found north of Mexico are almost entirely beneficial to man. Infrequently they become nuisances or pose public health problems. Unfortunately, most bat complaints arise from an exaggerated fear of bats, not from any actual damage; however, some form of management is justified and the type of management depends upon the problem.

Fear of rabid bats, as well as sensational and inaccurate news coverage, has engendered the use of potentially dangerous chemicals to kill bats in buildings. This may create worse public health hazards by increasing contacts between humans and sick bats, in addition to exposing people to dangerous pesticides through contact, inhalation, or ingestion of contaminated food. The conspicuous decline of bat populations, the excessive use of toxicants to kill bats in buildings, and the need for effective methods of bat management have led to the preparation of this manual. The purpose of this publication is to provide a better understanding of the biology and ecological role of insectivorous bats and to describe their occasional conflicts with people and how these may be alleviated. The present methods and practices in house bat management are reviewed and promising areas for further investigation are suggested. Special emphasis is placed on "batproofing" or exclusion as the soundest long-term solution for the management of house bats.

One of the best deterrents against house bats is to improve the energy efficiency of a house by insulation, weatherstripping, and caulking. The Internal Revenue Service (IRS) has informed the U. S. Fish and Wildlife Service (FWS) (IRS, personal communication) that these energy-conserving methods, besides lowering heating-cooling costs and providing long-term batproofing, are also eligible for a Federal residential energy tax credit as provided by the Energy Tax Act of 1978 (Public Law 95-618). In addition to the Federal energy tax credits, 43 States grant some sort of tax benefits to residents who spend money to reduce their energy use (Anonymous 1980c).

In this manual, the term "management," rather than "control," is preferred. To some, control implies the reduction of bat populations without regard for the welfare of the target species, whereas management is directed at resolving the conflict without long-term adverse effects on bat populations. Animal Damage Control (ADC) activities of the FWS are confined to the target species and applied to individuals or local populations of bats in a house, church, school, or other buildings, and do not result in long-term injurious effects. Killing bats with chemicals is unnecessary and may, in fact, create more serious health hazards than are present without lethal control.

House bat problems vary widely due to multiple types of structures, construction, materials, age, and other factors so that no single method can be recommended to solve all problems. Often a combination of methods should be employed. The recommended approach to house bat management is "Integrated Pest Management" which utilizes biological, physical, and chemical controls as well as habitat modifications (Bottrell 1979).

Review of Biology and Ecology of Insectivorous Bats

Bats are the only truly flying mammals and belong to the order Chiroptera — "handwing." Their ability to fly, their secretiveness, and their nocturnal habits have undoubtedly contributed to bat folklore, superstition, and fear.

Bats are worldwide in distribution but mainly tropical. There are 18 families of bats and about 900 species — only the rodents exceed them in number of species within the class Mammalia (Tuttle 1979*b*). Bats are common in all the United States. About 40 species are found north of the Mexican border occurring from coast to coast and into the mountains, although they are most abundant in the Southwest (Barbour and Davis 1969).

The natural habitat of most North American bats is caves and trees. Many bats are found in mines and some in buildings. Day roosts are dark and secluded. Foraging areas are around water, forests, ravines, and buildings. With the advent of cold weather bats migrate or hibernate in caves, mines, and sometimes in houses. These hibernacula usually have high humidity and above freezing temperatures. Active, non-hibernating bats spend the day hanging in secluded retreats and become restless as evening approaches. Upon leaving their roosts to feed, bats usually first fly to a pond or other water source to drink. A second feeding period may occur just before daylight.

Most bats in the United States and Canada are insectivorous, catching small flying insects, many harmful, by sonar or echolocation. Some bats may consume up to one-half their weight of insects in a night. The little brown bat (*Myotis lucifugus*) commonly found in buildings, feeds on midges, mosquitoes, caddis flies, moths, and beetles. One study found 140 mosquitoes and other insects in the stomach of a single little brown bat (Bellwood and Fenton 1976; Anthony and Kunz 1977). Tuttle (1979*b*) stated that 500 bats can easily capture 500,000 insects a night.

The big brown bat (*Eptesicus fuscus*), also found in buildings, may fill its stomach in 1 h. Gould (1955) found that an adult accumulated food at a rate of 2.7 g/h. Seven orders of insects, including beetles and stinkbugs, are eaten (Phillips 1966). Many of the insects reported are harmful.

The Mexican free-tailed bat (*Tadarida brasiliensis*) forms the largest colonies of any mammal. Some Texas cave colonies contain as many as 20 million individuals and could consume more than 45,000 kg (100,000 lb) of insects nightly (Tuttle 1979*b*).

Many animals use sonar to navigate, locate, and avoid obstacles. Bats use sonar for those purposes and to capture flying insects. High-frequency sounds, inaudible to humans, produce echos permitting bats to measure distance. Bats also make audible sounds.

In the United States bats mate in the fall and winter but the female may retain sperm in the uterus until spring when ovulation and fertilization take place. Pregnant females congregate in nursery colonies in caves, mines, buildings, or other dark retreats. No nests are built. Birth occurs from April through July and most species produce a single young, although some have twins and a few have litters of three or four. Young bats grow rapidly and are able to fly within 3 weeks. When adept at flying and catching food, juveniles become less dependent on their mothers and the maternity colonies disperse after weaning in July and August.

Around first frost bats prepare for winter. Some species migrate relatively short distances, whereas certain populations of the Mexican free-tailed bat may require migratory flights up to 1,600 km (1,000 miles). Bats in the northern United States and Canada may hibernate from September through May; hibernation for the same species in the southern part of their range may be shorter or even sporadic, and some fly during warm spells in winter (Davis 1970).

Unlike many small mammals whose average life-spans may be less than a year, bats often live 10 years or more. Two little brown bats were recaptured 29 and 30 years after being banded (Keen and Hitchcock 1980).

Almost all bats are of some economic importance and those of the United States and Canada are beneficial because of their insectivorous diet. The guano (accumulated bat droppings) is rich in nitrogen and at one time was commercially mined in the Southwest (Gile and Carrero 1918; Nelson 1926) and is still mined in Mexico as nitrogen-rich fertilizer. The importance of bat guano has declined because of reduced populations of guano-producing bats and the development of inorganic fertilizers.

Several bat species in the United States have declined in numbers during the past 20 years (Barbour and Davis 1969; Tuttle 1979*a*, 1979*b*). Jones (1971) suggested that the widespread use of pesticides has been a major, but not the sole, reason for these reductions. Chemical pesticides have decreased the food supply for insectivorous bats, and ingestion of contaminated insects has resulted in reduced bat populations (Geluso et al. 1976). Thousands of bats die annually when people disturb hibernating or maternity roosts. Bat species in the northeastern United States have gradually declined where insecticides and rodenticides have been widely used in an attempt to solve house bat problems.

Nuisance Problems

Why Bats Become a Nuisance

Some bat species use man-made structures in preference to their natural roosts, whereas others are forced to roost in buildings when natural roosts, such as caves and hollow trees, are destroyed (Fig. 1). Some caves (Fig. 2) are ruined by flooding, dam construction, burning of debris (Jones 1971) or by pesticides (Mohr 1972). Cave roosts also are destroyed by explosives used in mining and quarrying, vandalism, and tourism (Mohr 1972). Bats hibernating in

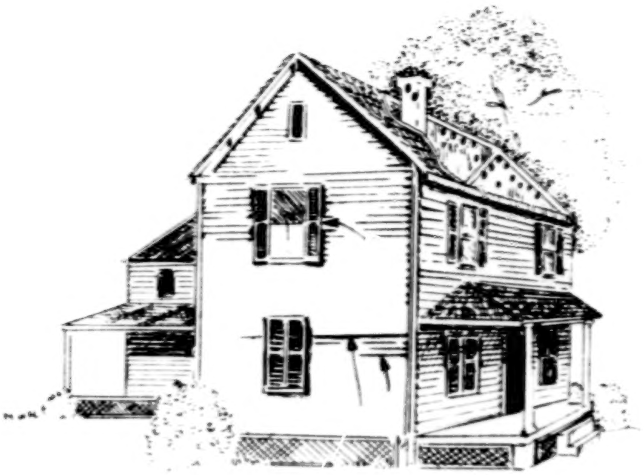

Fig. 1. Possible roosting sites in a house. (From Greenhall and Paradiso 1968)

winter have been deliberately killed by vandals or unintentionally by speleologists and biologists because activity resulting from disturbance depletes the bats' limited fat reserves (Mohr 1972). Forest management and deforestation, particularly removal of diseased or old trees with hollows (Fig. 3), have also reduced the number of available natural bat roosts (Jones 1971).

In recent times bat colonies in houses appear to be less tolerated. Entire local bat populations, whose maternity roosts were in buildings, have been purposely destroyed. Bats that have adapted from one roost type to another are now imperiled by changes in human tolerance of bats and by changes in building construction, i.e., cavity wall insulation, modern churches without belfries, flat gravel roofs, and less use of attics and shutters.

The general requirements for bat roosts in buildings are known. Colonial bats that live in houses usually occur in areas near water and at the edges of woods where insects are found in adequate numbers (Fenton 1970). Less well known is the importance of other factors that govern roost-site selection such as temperature, humidity, vegetation, and the physical characteristics of roost sites. Older structures are particularly attractive to bats.

When Bats Cause Problems

Bat colonies may cause a nuisance when they are located in buildings. The noise created by bats squeaking, scratching, scrambling, and crawling in attics, walls, and in chimneys can be objectionable if the roost site is close to human living quarters. Bats nearly always reveal their presence by their fecal droppings left beneath entrance holes and below roosts. Brown stains and odors from urine, feces, and glandular body secretions, found near the eaves of wooden buildings and barns, may often indicate the presence of bats inside the structures. In old, loosely constructed buildings where there is an attic roost or a space between the wall and a chimney, excreta may seep through cracks and stain ceilings and walls. In churches, bats frequently enter through unscreened belfry louvers and leave droppings that are plainly visible on the front door stoop (Stebbings 1976).

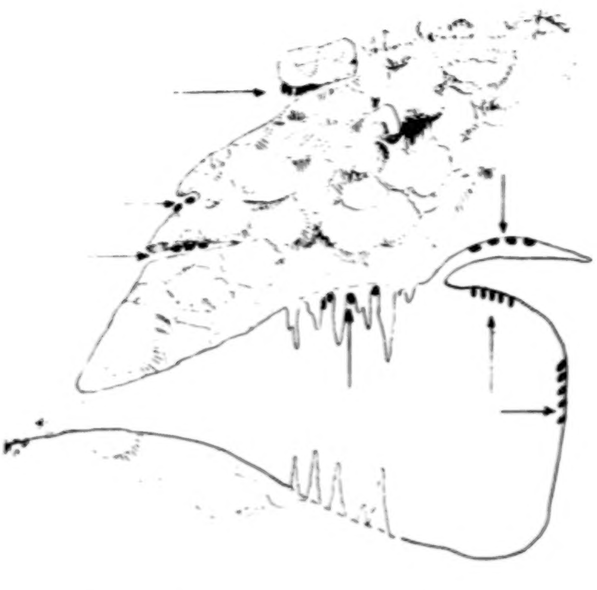

Fig. 2. Possible roosting sites in a cave and under rocks. (From Greenhall and Paradiso 1968)

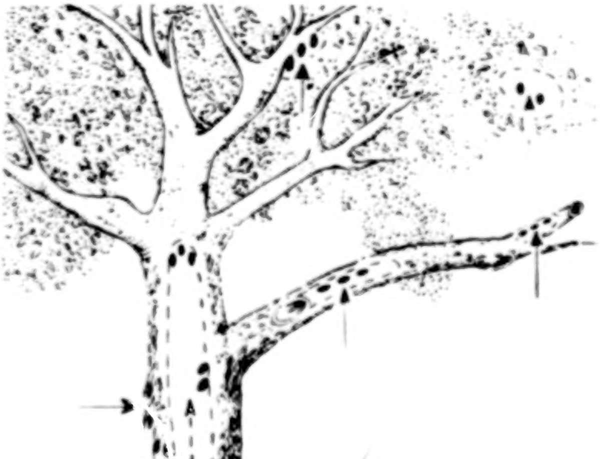

Fig. 3. Possible roosting sites in trees. (From Greenhall and Paradiso 1968)

Types of Bat Problems

Bats Inside Buildings

The discovery of one or two bats in a house is probably the most frequent problem. The large brown bat accounts for most of these sudden appearances. Common in towns and cities, it often enters homes through open windows or ungrated fireplaces. These bats may occur singly, in pairs, or in small groups. If unused chimneys are utilized for summer roosts, the young may fall or crawl through the damper and into the house when they are learning to fly and their parents may follow (M. D. Tuttle, personal communication). Sometimes one or more bats may appear in a screened room, and then disappear by crawling under a door crack. In the latitude of New England, the big brown bat frequently hibernates in houses or public buildings (Godin 1977), gaining entrance through crevices between the outer wall and the chimney, by a crack around a window, or through holes between loose boards or bricks. These bats may suddenly appear in midwinter during a warm weather spell and fly about the house. Migratory bats occasionally enter buildings overnight during their spring and fall migrations. A bat will usually find the way out by detecting a fresh air movement; therefore, the simplest solution to rid the building of the bat is to open all windows and doors leading to the outside. If it is still present at nightfall, the lights should be turned off to help the bat find open windows or doors. If the lights are turned on, the bat may seek refuge behind drapes, curtains, and wall hangings. Bats usually will not attack a person even when chased. If the bat refuses to leave, it can be caught in a net, small box or can, or in a gloved hand and released outside. Alternatively, local health authorities can be called to collect the bat (Fig.4).

Most bats are able to squeeze through surprisingly narrow slits and cracks; the smaller species require an opening no wider than 9.5 cm (3/8 in.) or a hole the diameter of a dime. The little brown bat can enter a space 1.6 by 2.2 cm (5/8 by 7/8 in.); the large brown bat can squeeze through an opening 3.2 by 1.3 cm (1-1/4 by 1/2 in.).

Attractive openings are found in old frame structures where boards shrink, warp, or become loosened. Bats commonly enter buildings through the overhang of the roof made by overlapping sheeting or drop siding. They are most often found in attics, between roofs and ceilings or roof spaces, in cornices, fascias, or other crevices around the roof, in walls, in chimneys, around drainpipes, behind rafters and sheathing in open barns, between a window and screen, and occasionally in crawl spaces. Depending on the size of the space and on the species, bats will be found singly, congregated in groups of a few individuals, or in colonies of hundreds and occasionally thousands.

Guano, Urine, Odor, and Ectoparasites

Bat guano and urine accumulating in attics and wall spaces attract arthropods such as roaches and mites (Constantine 1970). The accompanying odor can be pungent but not dangerous. Bat ectoparasites, such as ticks, mites, fleas, and bugs, rarely attack humans (Scott 1963). They are most likely to cause a nuisance after a house has been batproofed, thereby ridding the edifice of bats but leaving arthropods. Arthropod problems are unlikely except in large, well-established bat colonies where fumigation may be appropriate (Pratt 1958). Ectoparasites quickly die in the absence of bats.

Fig. 4. Member of New York City's Bat Squad. (Photo by Stephanie Marcus)

Bats Outside Buildings

Some bats temporarily roost behind shutters, under wood shingle siding and roofing, roof gutters, awnings, trim with overhang, under flashing around chimneys which has separated or loosened from the solid structure, open garages, patios, porches, breezeways, open livestock shelters, and under sheets of tarpaper. Shutters on brick houses are especially attractive as day roosts for transient bats in migration and for males that frequently take refuge behind shutters during the nursing season. In exceptionally hot weather, individuals may abandon an attic and reside behind shutters. Big brown bats are partial to roosting behind the trim below roofs of houses. Unusual roosting areas include sewers, wells, and graveyard crypts. Bats also will fly around swimming pools from which they may drink or catch insects that are attracted to water. Street and porch lights attract flying insects which in turn attract bats.

Distribution of Problems

House bat complaints come from throughout the United States (National Research Council 1980) and southern Canada. The greatest number originate from the Northeastern States: New England and adjoining Canada, New York, New Jersey, Pennsylvania, and Maryland. This distribution of complaints appears to be related to the attention given by news media concerning rabies (D. G. Constantine, personal communication). Additional bat complaint "hot spots" exist in Wisconsin, Illinois, and

Indiana. Numerous complaints also originate in Texas and California.

Human reactions to the presence of bats in buildings vary from place to place. Often bats that annoy one resident may be encouraged by a neighbor to coexist. House bat colonies are common in Florida but very few complaints (of bats in buildings) come from that State. This may be due to the abundance and variety of Florida wildlife living in proximity to people. In sharp contrast to Florida is New York City where bats roosting in buildings are rare and a single bat flying into a private apartment or office may generate instant panic. The solitary migratory red (*Lasiurus borealis*) and hoary bats (*Lasiurus cinereus*) constitute the major problem in New York City, especially Manhattan, by flying into office buildings where they have been observed as high as the 27th floor (A. Beck, personal communication). They are particularly abundant during the 3-month period beginning with August (Anonymous 1977).

Confusion of Bat Problems with Those of Other Animals

It is essential to verify that a nuisance is caused by bats. Twittering and rustling sounds in old chimneys, often attributed to bats, may be caused by chimney swifts (*Chaetura pelagica*). Scrambling, scratching, and thumping sounds coming from attics and walls may be caused by rats (*Rattus rattus*), mice (*Mus musculus*), or flying squirrels (*Glaucomys volans, G. sabrinus*). Bats often become noisy before leaving their roosts at sunset and may chatter on hot days when they move into walls to seek refuge from heat. Thus, an increase in noises about dusk probably indicates bats.

Droppings from insectivorous bats are easily distinguished from those of small rodents because of their friability. They are easily crushed by rubbing between the fingers which reveal shiny bits of undigested insect chitin (the exoskeleton of the insect). In contrast, rodent droppings are unsegmented, harder, and more fibrous (Greenhall and Paradiso 1968).

Occasionally the droppings of birds and lizards that feed on insects may be found along with bat droppings. Bat droppings never contain the white chalky (uric acid) material characteristic of the feces of these other animals.

Species of Bats Causing Problems

Among the 40 species of bats in the United States, only a few cause problems in buildings. The most common house bats congregating in groups or colonies are called colonial bats. Other species live a secluded or solitary existence and are known as solitary bats.

Colonial Bats

The three species most often encountered by humans are the little brown bat, big brown bat, and Mexican free-tailed bat.

The little brown bat is one of the most abundant species, often forming nursery colonies in buildings during the summer. Adults and young vacate the buildings in the fall to hibernate in caves and mines. Colonies may be as large as 2,000 (Humphrey and Cope 1976).

The big brown bat is undoubtedly the most familiar to humans and the only species for which buildings are ideal for both raising young and hibernating. Colonies are small, ranging from 12 to 200 (Barbour and Davis 1969).

The Mexican free-tailed bat is the most colonial of all bats. Its habits vary in different parts of the country. Primarily a cave dweller in the Southwest, a colony may include thousands of individuals. In Florida this bat never enters caves and thousands have been found in a single building. Some populations migrate 1,600 km (1,000 miles) to overwinter in Mexico whereas others are year-round residents (Davis et al. 1962).

Solitary Bats

Solitary bats live alone in tree foliage or under bark, but never in caves. The red bat, the hoary bat, and the silver-haired bat (*Lasionycteris noctivagans*) may occasionally enter buildings during spring and fall migrations as transients but do not permanently roost in buildings (Barbour and Davis 1969).

A number of other bat species are occasionally found in buildings but, because they infrequently cause problems, they are not discussed. Appendix A contains an identification key to the bats most often associated with houses, including detailed descriptions and photographs.

Public Health Hazards

Rabies in Bats

Rabies is the most important public health hazard associated with bats, but its impact has been vastly exaggerated. The first State to report rabies in a bat was Florida in 1953 (Venters et al. 1954). By 1978, rabies had been reported in 30 of the 40 bat species normally found in the United States and in all 48 contiguous United States, but no increase in the rate of infection has been detected (Constantine 1979*b*). In 26 years, there have been only eight human fatalities in the United States and Canada attributed to actual bites of rabid bats and two human deaths probably due to nonbite aerosol transmission (Table 1). Tuttle (1979*b*) noted that "Far more people die every year from dog attacks, bee stings, power mower accidents, or even from being struck by lightning." Unfortunately, newspaper reports and television coverage of bat bites are often sensational, exaggerated and grossly inaccurate, perpetuating misleading information. The Washington Post, 20 September 1979 carried this headline "WARNING: SICK BIRD MAY BE RABID BAT: 12 Million of the Winged Mammals to Pass Through Md. on Way South." On 17 August 1980, the Washington

Table 1. *Summary of 10 human cases of rabies attributed to exposure to insectivorous bats, United States and Canada, 1950–1979 (prepared by D. G. Constantine).*

Year of exposure	Locality	Bat species	Circumstances of exposure
1951	Big Spring, Texas	Unknown	Bitten while handling moribund bat. Bat not tested.
1955	Frio Cave, Texas	Free-tailed bats *(Tadarida brasiliensis)*	Airborne infection probable, 0.5% infected among millions of bats present.
1958	Magalia, California	Silver-haired bat *(Lasionycteris noctivagans)*	Bitten while handling moribund bat. Bat rabies positive
1959	Frio Cave, Texas	Free-tailed bat	Airborne infection probable, from 0.5% infected among millions of bats present.
1959	Blue River, Wisconsin	Unknown	Sleeping person bitten on ear. Bat not tested
1970	Willshire, Ohio	Big brown bat *(Eptesicus fuscus)*	Bitten on the thumb while asleep. Bat rabies positive. Patient survived.
1970	Saskatchewan, Canada	Unknown	Bitten on face while in bed. Bat not tested.
1971	Sussex County, New Jersey	Unknown	Person bitten on lower lip. Bat not captured.
1973	Lexington, Kentucky	Unknown	Bitten on ear while asleep. Bat escaped.
1976	Cecil County, Maryland	Big brown bat	Bitten while brushing bat off shoulder. Bat rabies positive

Post headlined a news item "Thousands of Bats, Some Rabid, Infest Hagerstown Homes." Such misleading accounts usually elicit intense public reactions that generate vociferous demands for complete bat destruction (National Academy of Sciences 1973; Mohr 1976). In addition, the following sequence of events usually occurs (D. G. Constantine, personal communication): application of some chemical (DDT or anticoagulant) to kill the bats which results in increased numbers of grounded bats, increasing the probability of human contact and anti-rabies treatment. If a dog or cat is involved, the pet may have to be either quarantined or destroyed (Constantine 1979*a*).

Rabies in insectivorous bats is generally similar to rabies in carnivores, differing in that bats fly, are rarely aggressive, and some species frequent buildings. Constantine (1979*a*) stated that about 10% of suspect bats submitted to health departments have rabies and less than 0.5% of seemingly normal bats have been found to have the virus.

In California, D. G. Constantine (personal communication) found, in 1979, that about 1 bat in 1,000 was rabid. He cautioned that figures cited about rabies occurrence in bats are frequently misleadingly high because they do not reflect random samples of wild populations.

Aerosol rabies transmission has been shown to be a hazard to humans and other mammals (World Health Organization 1973). It is not a public health hazard with house bats. The two probable airborne rabies cases were acquired in one cave in Texas occupied by millions of Mexican free-tailed bats (Constantine 1967*a*; Table 1). To demonstrate that airborne rabies occurred, foxes and coyotes died of rabies within the cave even though they had been placed in screened cages to protect them from bat bites. Although rate of infection among the bats was low the exceptional environmental conditions in the cave were conducive to aerosol transmission of rabies. Such transmission likely occurs in only a very few caves (Constantine 1967).

Post-exposure Prophylaxis

A safer and more effective vaccine against human rabies than Duck Embryo Vaccine (DEV) was approved by the Food and Drug Administration on 9 June 1980 (Centers for Disease Control [CDC] 1980). The new vaccine, human diploid cell rabies vaccine (HDCV), is an inactivated virus vaccine grown in cultures of human diploid cell tissues. HDCV induces active immune responses in about 7 to 10 days after just five injections. DEV is less efficient in producing immunity and requires 23 injections. In addition, adverse reactions with HDCV are less common than with DEV. HDCV is administered in the arm and is given along with rabies immune globulin, human (RIG). RIG provides rapid, temporary protection rarely causing adverse reactions. It replaces antirabies serum, equine, which causes serum sickness in over 40% of the adult recipients. Studies conducted in late 1979 in Germany and Iran confirmed the safety and effectiveness of the new vaccines (CDC 1980).

Bat bites should always be considered as potential rabies exposures. Immediate and thorough washing of all bite wounds and scratches with soap and water is probably the most effective measure for preventing rabies. Tetanus prophylaxis and measures to control bacterial infection should be given as indicated (Anderson and Winkler 1979; CDC 1980).

Post-exposure antirabies immunization should always include both passively administered antibody (preferably RIG) and vaccine (preferably HDCV). RIG is administered only once, at the beginning of antirabies prophylaxis to provide antibodies until the patient responds to vaccination. If RIG inadvertently was not given when vaccination was begun, it can still be given up to the eighth day after the first dose of vaccine is given. HDCV should be administered in conjunction with RIG and consists of five 1-ml doses given intramuscularly (in the deltoid regions). The first dose should be given as soon as possible after the exposure; an additional dose should be given on each of days 3, 7, 14, and 28 after the first dose. The World Health Organization (WHO) currently recommends a sixth dose 90 days after the first dose (CDC 1980).

A serum specimen for rabies antibody testing should be collected on day 28 (at the time the last dose is given) or 2-3 weeks after the last dose. If an adequate antibody titer is not detected, a booster dose is given, and another serum specimen for rabies antibody testing is collected 2-3 weeks later. Testing for rabies antibody can be arranged by the State health department.

Pre-exposure Immunization

The WHO Committee on Rabies—Sixth Report (1973) has recommended pre-exposure immunization against rabies for persons who run a high risk of exposure: bat biologists, veterinarians, pest control operators, and others whose pursuits might bring them in contact with potentially rabid bats should consider this precaution (Trimarchi 1978). Although it does not eliminate the need for additional therapy after a rabies exposure, it simplifies the therapy by eliminating the need for globulin and decreases the number of doses of vaccine needed. Three 1-ml injections of HDCV should be given intramuscularly (in the deltoid area), one on each of days 0, 7, and 21 or 28. All who receive pre-exposure immunization should have serum for rabies antibody testing collected 2-3 weeks after the last injection. If the antibody response is not adequate, a booster should be given and serum collected for antibody testing 2-3 weeks later. Persons with continuing risk of exposure should receive a booster dose (1 ml.) every 2 years or have their serum tested for rabies antibody every 2 years and, if the titer is inadequate, have a booster dose.

For assistance on problems or questions about rabies prophylaxis, pre-exposure immunization, or inadequate titer, call your local or State health department, or the Viral Disease Division, Bureau of Epidemiology, Centers for Disease Control (404) 329-3727 during working hours, or (404) 329-3644 nights, weekends, and holidays.

Prevention of Exposure to Bat Rabies

Most rabies exposures could be avoided if people simply refrained from handling bats. Because there have been a few confirmed bat-transmitted rabies deaths in humans, bitten persons are routinely treated to prevent rabies. Treatment is discontinued only if the bat can be shown to be rabies free. Pets that have been bitten and not recieved antirabies vaccination are either quarantined or destroyed. Unprovoked bat attacks on humans are extremely rare. Bites usually are defensive, occurring when people handle sick or moribund bats. Effective ways to minimize potential human-bat contact are (1) cautioning the general public not to handle bats and (2) exercising care in handling bats. Inexperienced people should never touch bats with bare hands. Bats can be picked up with gloves, forceps, or a stick. If a bat has bitten a person or pet, it should be captured, without destroying the head, and placed in a cloth or plastic bag. Dead bats should be shipped under refrigeration to the nearest health laboratory for examination.

Bat Rabies Control Policy

Since rabies has been detected in the majority of bat species and reported from the 48 contiguous United States, a few States have developed bat rabies control policies to assist county and city governments in coordinating their efforts with state public health departments. The State of California (1977) has a "Bat Rabies Control Policy" which can serve as a model. Requests for information should be addressed to the State of California Department of Health Services, Veterinary Public Health Unit, 2151 Berkeley Way, California 94704.

Histoplasmosis in Bats

Histoplasmosis is an airborne disease caused by a microscopic soil fungus, *Histoplasma capsulatum*, that affects the lungs of humans. It can masquerade as influenza, or with more severe symptoms, be misdiagnosed as tuberculosis. X-rays may show pulmonary lesions. The disease does not respond to tuberculosis treatment. Many infections in humans do not produce symptoms or cause distress. Skin and blood tests reveal the presence of an infection; however, a positive histoplasmin reaction may only be evidence of a previous infection (Tosh and Weeks, n.d.).

Nature and Distribution

Histoplasma association with house bats was first described by Emmons (1958) when several cases, including one human fatality, occurred among the occupants of a house in Maryland that contained a colony of big brown bats. In the United States and elsewhere, ecological studies have shown that the fungus is most frequently recovered from soils enriched by the excreta from bats and birds. In the United States almost 90% of all reported cases of human histoplasmosis occur in the central part, particularly the Ohio River and Mississippi River valleys, extending eastward into Virginia and Maryland (Hoff and Biglar 1981.) As yet, there are no records of the recovery of *H. capsulatum* from Canadian soil (L. Ajello, personal communication) or from bats or bat roosts elsewhere in the United States. The fungus is not found in all bat and bird habitats so that the geographic distribution of the fungus does not seem to be correlated with that of bats (Ajello 1969). In contrast to birds, bats are susceptible to histoplasmosis and the organism has been isolated from some species of bats in the United States. However, Ajello (1969) points out, "This has led to the ill-founded speculation that bats are active in the epidemiology of histoplasmosis." There is no evidence of transmission of the disease from bats to man. When soil containing the fungus is disturbed, the spores, and possibly hyphal fragments, become airborne and may be inhaled by people who enter bat roosts.

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Prevention and Protection

Fortunately, attics that have harbored bats for many years and contain sizable accumulations of guano are not generally located where human occupants are easily exposed. Relatively few people, even among those actually exposed to *H. capsulatum*, become seriously ill. However, there is potential risk of infection to anyone intending to remove the guano, due to spores released by the disturbance. Pest control operators and others proposing to undertake these tasks should be healthy persons with positive histoplasmin skin tests and clear chest x-rays. Some protection is possible by wearing respirators that fit properly and are capable of filtering out particles as small as 2μ in diameter or by using a self-contained breathing apparatus. The respirators should be approved for nuisance dusts by the National Institute for Occupational Safety and Health (NIOSH; Tosh and Weeks, n.d.). Dry guano should be dampened with water before its removal to further reduce the hazard of dust inhalation.

Soil Decontamination

Formalin is the most effective chemical for the outdoor soil decontamination of *H. capsulatum*. Because formaldehyde gas and liquid formalin are dangerous to humans, they are used primarily outdoors. A 3% solution of formalin could be used to decontaminate bat guano in an attic, but due to its hazardous qualities, extreme caution must be exercised (L. Ajello, personal communication).

Bat Repellents

Chemical

Commenting generally on chemical repellents, D. G. Constantine (personal communication) stated,

> Whereas there is an occasional need for properly applied chemical repellents, the need can be eclipsed by the problems that develop if the chemicals are misapplied. Unfortunately, circumstances usually guarantee that liquid repellents (usually sprays) are applied directly on the bats instead of on surfaces where they land. This has been observed to cause the affected bats to be grounded (after scattering for miles around in some cases), *presenting a far worse problem*. This points up a need for delivery of fumes rather than liquid in most instances. As in plugging access holes, one is limited to the late summer and early fall for application; otherwise, young flightless bats may be flushed (spring through mid-summer), or lethargic bats may be expelled (late fall and winter). Properly controlled, the latter procedure may be indicated in some expertly handled instances. In the vast majority of cases, the use of chemical repellents is superfluous, the desired results being achievable by plugging accesses. Moreover, chemical repellents are only temporarily effective.

Naphthalene

As of January 1981, naphthalene (crystals or flakes) is the only chemical registered by the Environmental Protection Agency (EPA) as a bat repellent for indoor roosts (EPA registration Number 462-19). Naphthalene should be spread on the floor or applied between the walls, using about 2.3 kg (5 lb) for every 60 m³ (2,000 ft³) which should be adequate to treat an average attic (EPA 1972). As the crystals or flakes vaporize, bats may be repelled. Heavier dosages, 4.5 kg (10 lb), may dislodge bats in broad daylight within a few minutes after introduction. The bats do not return so long as the strong odor remains, but will return when it dissipates. If necesary, the application may be repeated. Its efficacy is greatest when used in confined air spaces. Humans should avoid its inhalation and sensitive individuals are cautioned against all contact (Morgan 1977).

Non-chemical

Illumination

In Canada, Laidlaw and Fenton (1971) reported that a bat nursery was substantially reduced by artificial light. Floodlights strung through an occupied attic to illuminate all bat roosting sites may cause bats to leave and seek a new location. Large attics may require four or more 100-watt bulbs. A 150-watt spotlight is more effective. Fluorescent bulbs may also be used to illuminate dark areas.

The size of colonies in the roofs of nine Canadian houses decreased by up to 90% when they were subjected to constant illumination, whereas two unlit control colonies increased by 57 and 97%, respectively. In some situations it is difficult and costly to adequately light a roosting location. Illumination is cleaner than other methods and safer for both humans and bats.

Drafts

In open spaces where illumination might not work, the area may be made more undesirable for bats if it is possible to open doors and windows or otherwise create drafts. Carefully directed breezes produced by electric fans have successfully repelled bats according to Constantine (1979*a*).

High-frequency Sound

High-frequency sound has been used to repel or disperse bats. Hill (1970) connected 12 adjustable high-frequency (about 4,000 to 18,000 cps) dog-training whistles to oxygen cylinders located at various points in buildings at a nuclear power station. After 48 h of continuous operation 500 to 1,000 bats (species not mentioned) no longer occupied the building. Three dog whistles attached to a large aquarium pump also had a repellent effect on bats. It is believed that the high-frequency sound waves somehow either interfere with the bats' ability to navigate or otherwise disturbs them. Constantine (1970) mentioned that persons in the vicinity of the ultra-sound emissions became irritable and nervous.

Claims have been made that some variable frequency ultrasonic devices used for rodent control are highly effective against bats. However, Hurley and Fenton (1980) stated that ultrasonic rodent repellents they tested for the control of little brown bats were not effective.

The FWS has initiated research on auditory repellents. In 1974 a sonic device, the EI-700-A Bat-I-Cator, was evaluated in Maine, New Hampshire, and Massachusets (J. W. Peterson, personal communication). This device emits an intermittent high-pitched "beep" which it was hoped would repel bats from structures. It was tested in about 10 different sites. Peterson said, "In all cases, it was evident that the Bat-I-Cator did agitate, confuse and disorient the bats causing them to fly more erratically and to relocate away from the machine. Bat counts before and after using the machine did not indicate any appreciable reduction in numbers."

The EPA tested a number of rodent electromagnetic repellers which were removed from the market because they did not work for bats as claimed (Smith 1979).

Alarm and Distress Calls

Distress cries of bats can be used to attract other bats to nets or traps. Little brown bats and big brown bats responded to their own distress cries but not the cries of other bat species (Fenton et al. 1976). The authors emphasized the importance of ultrasonics but it is evident that a great deal is unknown about the role of vocalizations in bat behavior.

Contact Repellents

Sticky-type repellents, such as rodent glue boards, Roost-No-More, Tanglefoot, and Tacky Toes have been used in situations where roost surfaces and bat accesses may be coated. These glue substances may have to be replenished from time to time because dust causes them to lose their tackiness (Marsh and Howard 1977). Barclay et al. (1980) compared three methods used for controlling bats in buildings: use of sticky deterrents, DDT, and sealing access routes used by bats. They evaluated the effectiveness of two sticky deterrents applied around entrances to colonies of big brown bats roosting in three buildinges: Tacky Toes was applied as a paste in a 2-cm- (0.8 in.) wide, 0.5-cm- (0.2 in.) thick band onto masking tape surrounding each known access hole at two colonies, whereas Tanglefoot was applied in a 5- to 8-cm- (2- to 3.2-in.) wide coat around and inside the access routes used by bats at one colony. They found that "Sticky deterrents were the least successful, presumably because the bats were able to avoid the substances and because movement of the animals over the treated surfaces presumably reduced their effectiveness. Although repeated applications might have proved more successful, this method is no easier and is less permanent than sealing entrance and exit holes."

Bat Toxicants

Some public antipathy to bats, especially when they become a nuisance in houses, derives from phobias based upon myths. To many people bat prejudice suggests that the answer to problem bats is a bat toxicant. According to Constantine (1979*a*) "Killing the bats is contraindicated. This is true for a variety of reasons: (1) It is a waste of time, because the animals usually are replaced promptly by other bats; (2) Killing the bats has the effect of displacing the only permanent solution, which is physical exclusion; (3) Killing the bats is hard to justify, because the incidence of rabies infection is extremely low, and the animals are of value in insect control; (4) But the killing of bats is contraindicated primarily because the toxins likely to be used, such as DDT, scatter sick bats over wide geographic areas (Greenhall and Stell 1960) where persons and pets can be bitten as they investigate them."

The rationale for the use of chemicals to control bats in buildings has been the fear of human exposure to rabid bats. The effects of organochlorine insecticides applied to bats, their roosts, or both, to kill them has been reviewed by Clark (1981*b*).

DDT

During the late 1940's, DDT became a popular toxicant for bat control (Luckens and Davis 1964). The FWS held a registration for DDT (50% wettable powder) for bat control from 10 June 1966 to 12 October 1970. The FWS terminated the use of DDT and its recommendation on 2 July 1970. Two years later, EPA placed a general prohibition on the use of DDT except where certain public health hazards exist. Thus, DDT is the only chemical federally registered by EPA (Registration Number 36765-1) as a toxicant for bat control and it is necessary to obtain special approval for its use from CDC (Anonymous 1975).

On 28 May 1976, CDC became the agency responsible for the issuance of DDT for the control of bats inside buildings, where they constitute a demonstrated rabies health hazard. DDT can be used only by agencies approved by CDC. Only after practical alternative methods have failed will CDC provide, on approval of a request, one 300-g (10.5-oz) package of 75% DDT wettable powder (CDC no date; Lera and Fortune 1978).

Residues of DDT are known to be highly toxic to bats. This compound was evaluated by Greenhall and Stell (1960) who found that it killed bats for at least 1 year. These authors found that bats were poisoned and scattered for as long as 4 years after an application (unpublished observations). Kunz et al. (1977) studied the mortality of a little brown bat colony following multiple applications of DDT and clordane, noting persistent kill for more than 4 years. Kunz revisited the roost in 1979 and found that DDT continued to kill bats 6 years later (personal communication). Barclay et al. (1980) quantitatively compared the effectiveness of DDT, sticky deterrents, and sealing access routes for controlling colonies of big brown bats in buildings. Their results confirmed those of Kunz et al. (1977) that the use of DDT is ill-advised. Lethal bat contacts could continue for years after the poisons have been applied; also, bat human contacts increased after treatment. Trimarchi (1978) suggested that physiological stress could activate latent rabies virus and sublethal doses of pesticides may increase the local incidence of rabid bats. Barclay et al. (1980) stated, "this situation constitutes a strong argument against the use of pesticides to control bats."

There are other obvious and serious human health hazards, such as carcinogens, associated with the use of a persistent toxicant (DDT), in the closed areas of a home. In a loosely constructed building, DDT, whether used as a spray, dust, or powder can seep down into the living quarters. Since DDT is highly persistent (more than 30 years; Pimentel 1971), it is conceivable that an old bat roost regularly treated with DDT and later dismantled could be harmful to humans.

In discussing the testing of vertebrate pesticides for use in disease control Beck and Jackson (1977) stated, "The use of DDT or other chlorinated hydrocarbon sprays against rabid bats is perhaps the worst possible approach. These methods also disperse the colony, cause lingering mortality just as the disease does, and increase human contacts and the attendant panic with an often inaccurate press."

A recent technique reported by Clark (1981*a*) enables the accurate diagnosis of deaths of bats from organochlorine pesticides on the basis of residues in carcass fat. The technique is thus applicable for use with bats whose brains were removed for rabies testing before the possibility of pesticide poisoning had been considered.

Anticoagulants

Although no anticoagulant is federally registered by EPA for bat control, a powdered anticoagulant (chlorophacinone) has been registered for rodents and can be registered by individual States for restricted use under Section 24(c) "Special Local Needs," (SLN) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended (EPA 1976). Nevertheless, the hazardous nature of chlorophacinone for house bat control was demonstrated in a major prosecution of a Minnesota pest control operator for the misuse of Rozol in bat control work (EPA 1980). In a wideranging, 50-page opinion, Judge Marvin E. Jones ruled on 8 May 1980 that the use of Rozol for bat control constituted a public health hazard.

Constantine (1979*a*), who testified on behalf of EPA, made the following comments on the use of chlorophacinone dust to kill bats: "This method was similarly unproductive, accounting for the destruction of not more that ten percent (usually far less) of resident bats, despite applications of massive amounts of the material to attic ceilings and walls. In addition to scattering sick bats, this method endangers the public health to an alarming extent by exposing house occupants to the anticoagulant through contact, inhalation, or ingestion through contamination of food. Furthermore, the cat that brings the contaminated poisoned bat into the house will get anticoagulant in its mouth, and the child, parent, animal control officer, and laboratory workers who handle poisoned bats can be expected to get the material on their hands. Like products have passed through the skin." Constantine also noted that the uses of anticoagulants would present similar problems of increased human contact with moribund bats as with other slow-killing pesticides such as DDT. The recognition and treatment of anticoagulant poisoning is described by Morgan (1976).

Fumigants

Although some fumigants (methyl bromide, hydrocyanic acid, and sulfuryl fluoride) have directions for fumigating entire buildings, none of these highly toxic chemicals, which can be applied only by trained professionals, are currently registered for bat control. Such pesticides should be considered for bat control only in a real public health emergency, as established by the appropriate State or City health officials, and only after all other feasible methods have been tried and failed. Treatment of fumigant poisoning is described by Morgan (1977).

Batproofing

Batproofing in the United States was first described by Silver (1935). Silver wrote, "THE MOST SATISFACTORY and the only permanent way of obtaining freedom from the batroost nuisance . . . is to shut the bats out. This may be called 'batproofing' the building." Forty-five years later it is still the only effective long-term solution. It was also advocated by the FWS in 1944 (Silver and Jones 1951).

Usually there are only a few openings to a house bat roost, and batproofing is relatively simple because visible bat accesses can be easily located and blocked. However, some very old homes having large attics with dormers may have many small, obscure holes and be more difficult to batproof.

Internal Revenue Service—Residential Energy Tax Credit

One of the best deterrents against house bats is to improve the energy efficiency of the house by insulation, weatherstripping, and caulking windows, doors, and other gaps between the exterior and interior of the house. This will not only reduce the passage of hot or cold air and moisture but it will also eliminate openings used by bats to gain entrance into the home. These energy-conserving methods, besides lowering heating cooling costs and providing long-term batproofing, are also eligible for a Federal residential energy tax credit (IRS, personal communication) as provided by the Energy Tax Act of 1978 (Public Law 95 618). This statute provides a residential energy tax credit of 15% of the first $2,000 of expenditures made on or after 20 April 1977 and before 1 January 1986 with respect to the taxpayer's principal residence, the construction of which was substantially completed before April 1977. Income tax regulations, providing the public with guidance needed for determining whether a residential energy tax credit is available, were published on 29 August 1980 in the Federal Register, 45 F. R. 57712.

In addition to the Federal energy tax credits, 43 of the United States grant some sort of tax benefits to residents

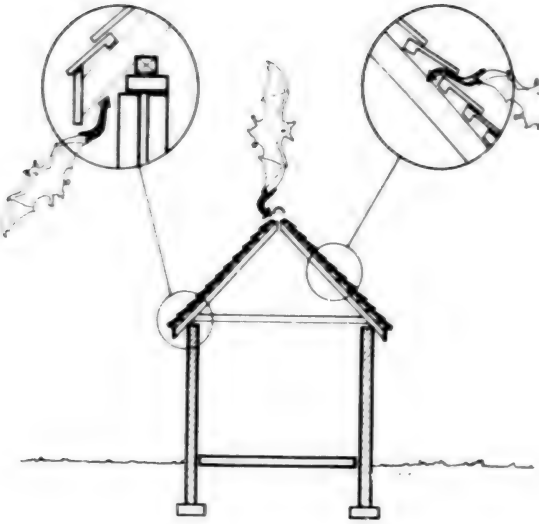

Fig. 5. Bats enter under eaves, at badly fitting ridge, and under shingles, slates, tiles. (By J. Newel Lewis, Dip. Arch., F.R.I.B.A. Trinidad and Tobago)

who spend money to reduce their energy use (Anonymous 1980c).

Location of Openings

Sources of air leakage may also provide access to bats. In very old frame houses with clapboard sidings, one should look for openings under overhangs where wood may have warped, shrunk, or decayed, leaving small, frequently obscure, spaces and holes suitable for bat entrances. Other bat accesses and heat loss openings are loose vents, cracks under loose flashing, eaves, cornices, louvers, where roof joins building, under corrugated roofing, spaces under doors and around windows, and openings where electrical wiring, outlet boxes, and water pipes enter the house (Fig. 5).

Fans—"Blower Door"

Because bats can crawl through narrow slits and apertures, these inconspicuous openings must be located and sealed for effective bat exclusion. Such holes may be located exactly by techniques used in airflow and conservation of energy studies to find where heat loss occurs in houses. D.T. Harrje and G.S. Dutt (personal communication; National Geographic Society 1981:48–49) briefly described the Princeton University's "House Doctor" methods for locating obscure holes in buildings where heat leaks occur. A house doctor is a trained specialist who, by means of instrumentation, diagnoses the heat losses in a house and provides methods to partially reduce these losses. House doctors usually work as a team of two and actually perform a partial retrofit of the house before leaving. Unlike energy auditors, who only make recommendations to save energy, house doctors require instrumentation to detect unusual and obscure heat losses. The instrumentation usually includes a "blower door" which is a door with a powerful fan mounted in it. This door may be attached to the front or back door frames of a house (Fig. 6). The fan can be set to create an overpressure (or underpressure) within the house relative to the outside.

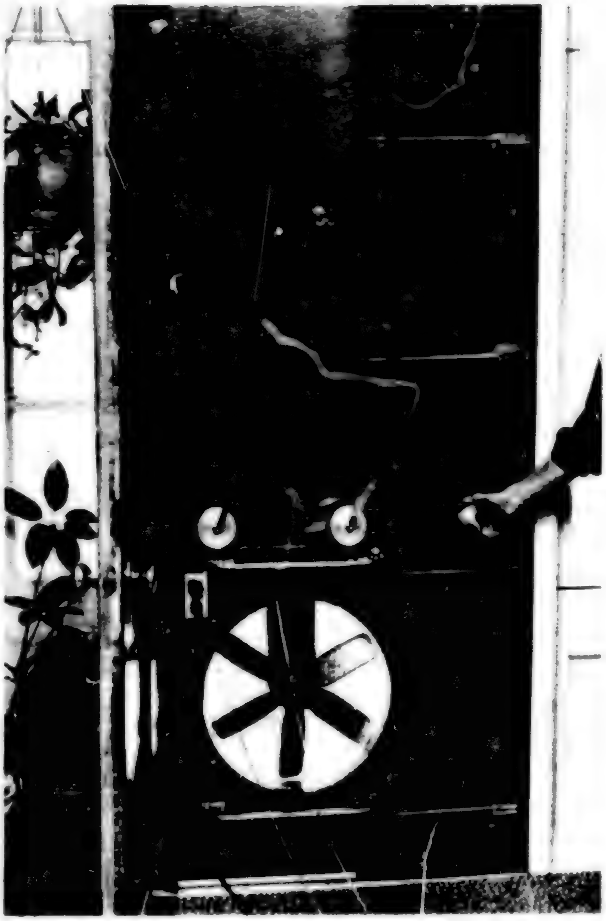

Fig. 6. Blower door from Princeton University house doctor approach. (Photo by David T. Harrje)

These fans exaggerate the airflow through all openings in the house so that air leaks can be detected by an extremely sensitive infrared scanner or by various "smoke" producing devices. To improve effectiveness, obvious outlets such as doors, windows, dampers, and ventilators should be closed. Fireplaces may need to be sealed with polyethylene sheets and tape to prevent excessive air leakage. The access door or trapdoor between the living space and the attic should be open. In house bat management, the search for obscure holes will be primarily in the attic; therefore, the access door or trapdoor should be kept closed and an ordinary 50-cm (20-inch) house ventilating fan should be attached to an attic window or ventilator (if one exists).

Simple, but ingenious, homemade devices will locate the general direction of air leaks in a house. One consists of a piece of very thin bathroom tissue or extremely thin plastic film (such as used in grocery stores to wrap meat and carry

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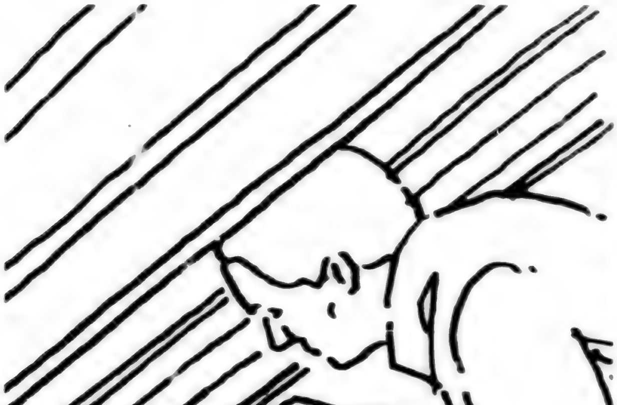

Fig. 7. Clothes hanger film tissue air leak detector. (Courtesy of Exxon Company, USA)

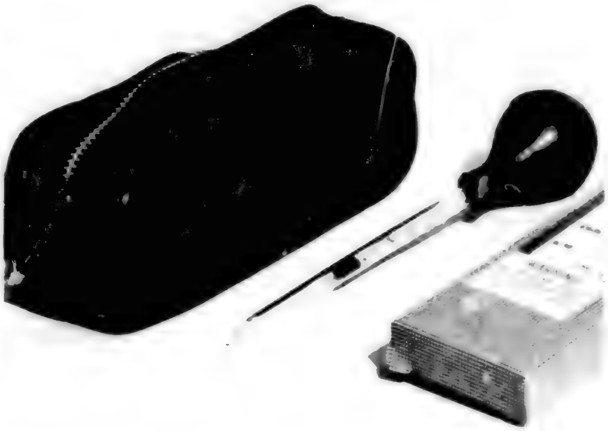

Fig. 8. Bendix GASTEC Air Flow Indicator Kit. (Photo courtesy of The Bendix Corporation, Environmental & Process Instruments Division)

produce or the type of film used by cleaners for garment bags) attached to a clothes hanger by two clothespins or tape (Anonymous 1980*a*; Rothchild 1980). The tissue and film are sensitive to small air movements, so when the gadget is placed in front of a wall outlet or window frame, a flutter in the materials indicates that air is causing the movement (Fig. 7). Another method used to test windows and doors for airtightness is to move a lighted candle around the frames and sashes. Any air movement will cause the flame to dance indicating that caulking and/or weatherstripping is needed.

The effectiveness of the weatherstripping may be simply tested by lighting a stick of incense or a cigarette and moving it close to a window on a cold windy day. The path of the curling smoke will pinpoint the source of any air leak (Anonymous 1980*a*).

Smoke Generators and Air Flow Indicators

For ordinary house bat work costly infrared scanners will not be necessary. Specific air leaks can be easily found by the use of an inexpensive air flow indicator, air tester, smoke generator, or smoke stick. One air flow indicator consists of a rubber bulb and a glass airflow tube (Fig. 8). The tube contains a porous substance impregnated with a small quantity of fuming sulphuric acid. The tips of the tube are broken off and one end of the tube is inserted into the mouth of the rubber bulb. When the bulb is squeezed air is forced through the tube causing a small amount of white smoke to emerge from the tube. Faint air currents will become visible by the smoke and reveal their source (Fig. 9). The airflow tube can be used repeatedly until the smoke is exhausted. If a test is interrupted the tube can be sealed at each end with rubber caps and stored until used again. No mask is required but as the smoke contains aerosol acidic properties, care should be taken not to inhale the fumes. Since no heat is

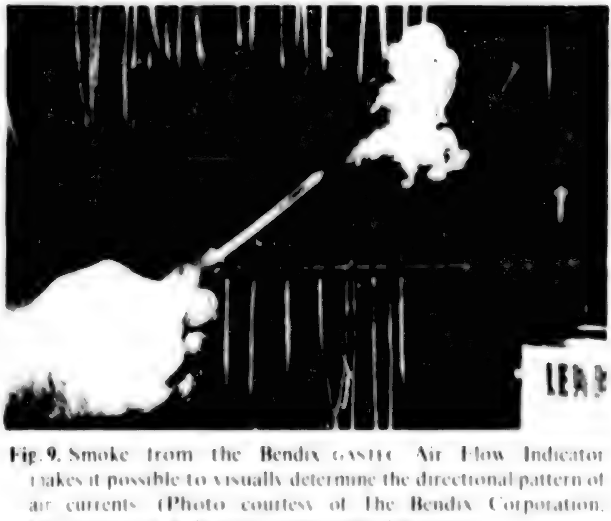

Fig. 9. Smoke from the Bendix GASTEC Air Flow Indicator makes it possible to visually determine the directional pattern of air currents. (Photo courtesy of The Bendix Corporation, Environmental & Process Instruments Division)

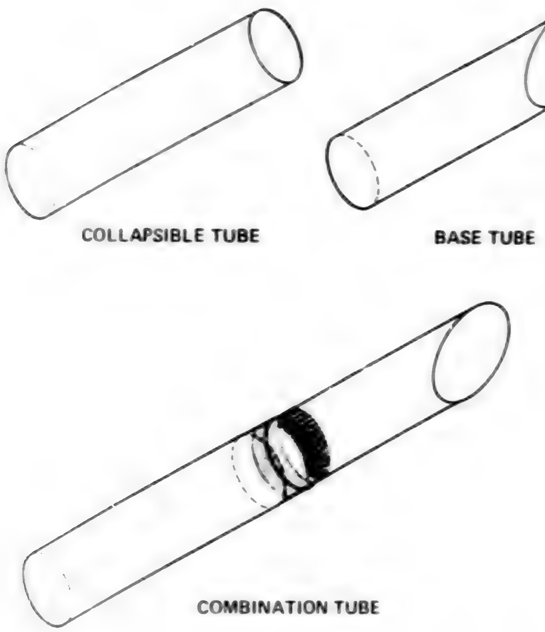

Fig. 10. Constantine's batproofing valve-like device. The lightweight, pliable, collapsible tube overlaps the heavier, rigid base tube, to which it is attached with tape. (Illustration courtesy of D. G. Constantine)

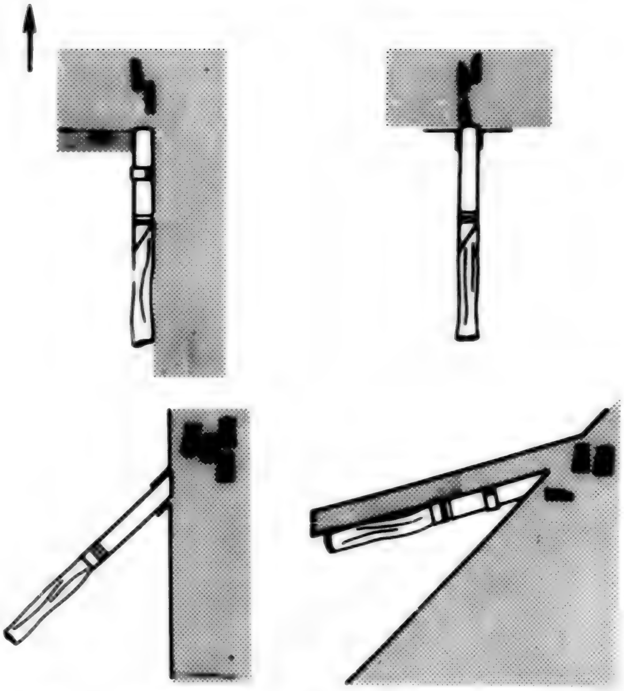

Fig. 11. Constantine's valve-like batproofing device placed in various installations. Bats in the dark stippled area of the house interior are about to enter tube. (Illustration courtesy of D. G. Constantine)

liberated during smoke generation, there is no fire hazard. This airflow indicator kit may be obtained from the Bendix Corporation, Environmental and Process Instruments Division, Largo, Florida 33540.

Another type of smoke stick utilizes titanium tetrachloride which combines with air to form a nontoxic, dense, persistent white smoke. The end of the smoke stick has a cotton swab, which when crushed, produces a stream of smoke, about twice the amount as from a burning cigarette, for about 10 min. Invisible air currents then will become visible by the smoke and traced to their source. By taping a smoke stick to a pole it is possible to locate air currents in difficult to reach parts of the attic. Smoke sticks of this type may be obtained from the manufacturer, E. Vernon Hill, Inc., P. O. Box 14248, San Francisco, California 94114.

The density of the smoke generated depends on the humidity present in the atmosphere and increases with increased humidity. Thus smoke generated in completely dry air will not be visible, nor will the smoke function well if the temperature within the test area is the same as outside the house. To remedy this, the use of the blower door would eliminate the dependence on natural ventilation (D. T. Harrje, personal communication).

Obscure openings may also be located from outside the house by means of smoke candles or smoke bombs which, when ignited, produce dense white or colored smoke. Depending on size, these smoke generators will burn from 30 s to 5 min. One or more are ignited and placed inside a metal container, such as a drum or trash basket, which can be covered. Holes around the upper part of the receptacle permit the smoke to escape and mix with the indoor air. After the smoke has filled a portion of the house, its interior is pressurized with a blower door or high-flow ventilating fan. This forces the smoke out of the house and points of air leakage may be seen from the outside and marked with chalk. Smoke leakage also may be observed indoors when smoke emerges through openings in the floor, ceiling, attic, and basement.

Timing

Bats should be out of the building before batproofing begins. The best time for batproofing is in the fall after the young bats have learned to fly and before the advent of cold weather. The time of day is also important so that holes can be blocked in the early evening after the bats have departed to feed. Most bats start to leave a building about 15 min after sunset; however, some species of bats leave their roosts later than others, some when it is dark.

Constantine's Batproofing Valve-like Device

One of the most discouraging problems encountered in batproofing has been the necessity to seal the last opening at night after the bats leave the house. This difficulty has been overcome by means of a valve-like device installed in the last exit(s) (Figs. 10, 11).

D. G. Constantine (personnal communication), having observed that batproofing can be discouraging when bats are in residence because of the necessity for night work, described a method that enables the work to be done in daytime. "After all entries except the primary one(s) have been sealed, a one-way, valvelike device is installed in the remaining opening(s) permitting the bats to exit after dark but preventing reentry. The bats depart through a smooth tube. Because some bats could reenter by hunching their way up the tube, soiling its surface and improving traction, the tube's end should be pliable enough to collapse closed when bats try to reenter. The device can be left in position for prolonged periods to permit lethargic or hibernating bats to awaken and leave. It should not be used from 1 May through August, when young, flightless bats may be in the roost. In due course the tube should be removed and the hole(s) sealed. A patent covering relevant methods and mechanisms has been applied for and a manuscript is in preparation."

Blocking and Sealing Holes

If Constantine's valve-like batproofing device is not available, it will be necessary to resort to the less practical procedures for blocking and sealing apertures. All obvious accesses should be sealed except one or two of the principal openings. For several days, bat counts should be made as the holes are closed, leaving the main exit open. On the night of the final count when all the bats have left, rags, tissue paper, or cotton should be pushed firmly into the main hole to prevent reentry. Returning bats may cluster or flounder outside the plugged entrance. Early the following evening, the plugging should be removed so as to allow any further bats to escape before sealing the last hole. If any bats are seen within the structure, the routine must be repeated. The house should be watched for several evenings at dusk (and later, if necessary) to make certain that bats have not found an overlooked access.

Batproofing Materials

Unlike rodents, bats will not gnaw their way through wood or building materials. Soft materials such as insulation batting can be easily attached to a building with a heavyduty staple gun.

Effective materials to exclude bats are those used in caulking, flashing, screening, and insulation. Weatherstripping, stainless steel wool, or stainless steel rustproof scouring pads are excellent materials to block long, narrow cracks.

Caulking

Cracks and crevices develop in a structure as it ages and bats will take advantage of these openings. Caulking will seal the openings.

To be eligible for caulking income tax credit, the IRS considers caulking as pliable material used to fill small gaps at fixed joints on buildings to reduce the passage of air and moisture. Caulking includes, but is not limited to, materials commonly known as "sealant", "putty," and "glazing compounds" (IRS 1980).

Since wood expands and contracts with the weather, it is best to apply the caulking during dry periods when the cracks will be their widest. Occasionally cracks enlarge and a filler is necessary before a caulking compound is applied.

Oakum is a tarred-hemp fiber commonly used to caulk ships. It packs easily and firmly by hand into small cracks. The tar or creosote binds the fiber so that it is not easily dislodged and also serves as a bat repellent. In addition to oakum, other fillers are caulking cotton, sponge rubber, glass fiber, and quick-setting putty.

There are various caulks which may be applied with a caulking gun. Latex, butyl, and acrylic have a durability of about 5 years and can be painted. Elastomeric types, such as silicone rubber and polysulphide rubber, will last indefinitely, expand and contract with the weather, do not dry or crack, tolerate temperature extremes, and come in colors. However, some cannot be painted. "Silicone rubber, according to Harrje (1978), is clear, long lasting (10-year guarantee), and almost invisible, thus matching any decor." Recently self-expanding urethane foams for caulking have appeared in pressurized containers and are dispensed similarly to shaving cream. When the material is placed in a hole it will expand several times to fill the space. After it cures and hardens, it may be trimmed, sanded, and painted with any type of paint or stain. Princeton University has used such self-expanding urethane foams as "Polycel One," "Great Stuff," and "Touch-n-Foam" (D. T. Harrje, personal communication).

Houses may need to be caulked in the following places where bats may enter:

- Between window drip caps (tops of windows) and siding
- Between door drip caps and siding
- At joints between window frames and siding
- At joints between door frames and siding
- Between window sills and siding
- At corners formed by siding
- At sills where wood structure meets the foundation
- Outside water faucets, or other special breaks in the outside house surface
- Where pipes and wires penetrate the ceiling below an unheated attic
- Between porches and the main body of the house
- Where chimney or masonry meets siding
- Where storm windows meet the window frame (except for drain holes at window sills)
- Where the wall meets the eave at the gable ends of a heated attic

Weatherstripping

When bats crawl under doors, the space between the floor and the door bottom may be sealed with weatherstripping, a draft shield, or a gap stopper to close off the space between the bottom of the door and the door sill or threshold. Weatherstripping is made of a variety of materials including

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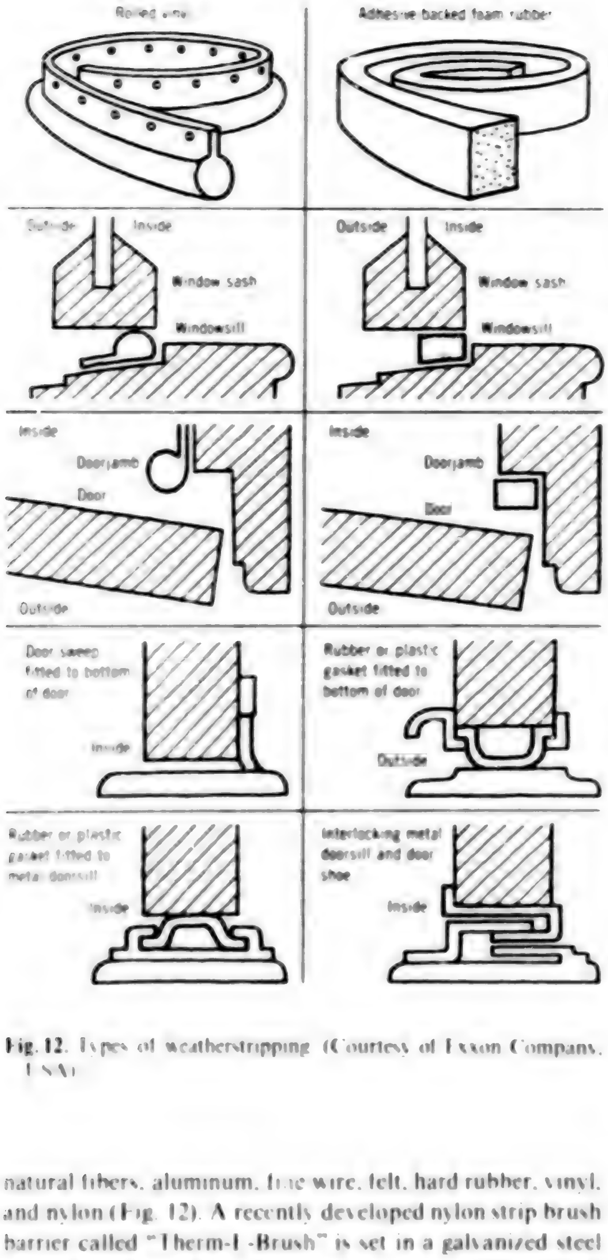
Rolled vinyl
Adhesive backed foam rubber
Outside
Inside
Window sash
Windowsill
Outside
Inside
Window sash
Windowsill
Inside
Doorjamb
Door
Outside
Inside
Doorjamb
Door
Outside
Door sweep fitted to bottom of door
Inside
Rubber or plastic gasket fitted to bottom of door
Outside
Rubber or plastic gasket fitted to metal doorsill
Inside
Interlocking metal doorsill and door shoe
Inside

Fig. 12. Types of weatherstripping (Courtesy of Exxon Company, USA)

natural fibers, aluminum, fine wire, felt, hard rubber, vinyl, and nylon (Fig. 12). A recently developed nylon strip brush barrier called "Therm-L-Brush" is set in a galvanized steel channel and housed in either aluminum or vinyl (Fig. 13). It has several advantages over ordinary weatherstripping. The flexible nylon filaments, which comprise a substantial brush, move easily in any direction permitting the bristles to conform to uneven floor surfaces, including carpet. This seals any gaps, stops drafts, and reduces heat loss. It is said to resist rodents and insects.

A simple draft excluder for the bottom of seldom-used doors is a long, flexible, sausage-shaped cloth tube filled with sand, which is simply pushed against the crack at the bottom of the door (Anonymous 1980*b*).

To help determine one's eligibility for weatherstripping income tax credit, IRS defines weatherstripping as narrow strips of material placed over or in movable joints of windows and doors to reduce the passage of air and moisture (IRS 1980).

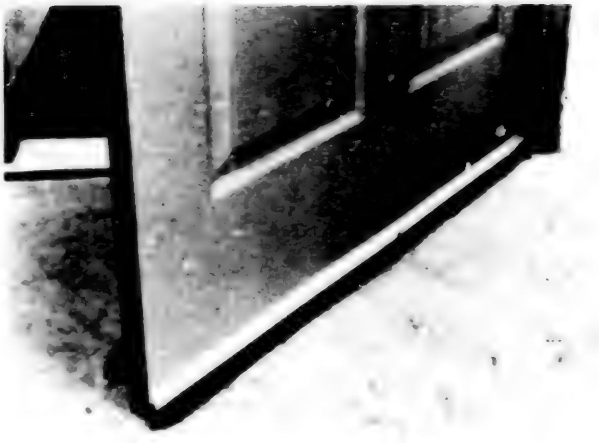

Fig. 13. Nylon strip brush weatherstripping—"Therm-L-Brush." (Photo courtesy of Sealeze Corporation)

Flashing

Wherever joints occur in a building, e.g., walls meeting the roof or a chimney, flashing may be installed to keep the building watertight. Flashing consists of strips of metal or other material to cover cracks, crevices, and holes. The materials most commonly used are galvanized metal, copper, aluminum, and stainless steel. A self-adhesive flashing, called "Flashband," was developed in 1965 and has been used to batproof buildings in England and western Europe for the past 10 years (R. E. Stebbings, personal communication). Flashband has advantages such as flexibility, self-adhesiveness, and a grip that reportedly improves with time despite extremes of weather. It is available in the United States and Canada.

Screening

Where screening is necessary the openings must be small enough to prevent the access of bats. steel hardware cloth should have 0.63 cm (¼ in.) mesh with three meshes or more to the inch. Insect screening for windows should be 18 × 14 mesh.

Bats can enter ventilators that are not properly screened. Hardware cloth for ventilators should be 8 × 8 mesh. Inlet and outlet ventilators should be properly installed. The type of ventilator used, its location in the building, and the direction of prevailing air currents may be important factors because buildings of identical design, but different orientation, vary in their attractiveness to bats. Many ventilators are made with metal louvers and frames, others are custom made of wood to more closely fit the house design (Fig. 14; Anderson 1970: Fig. 102; Anderson and Sherwood 1974).

The soffit (the underside of an overhanging cornice) usually has ventilators which may be continuous, round, single-framed, or the soffit itself may be of perforated hardboard. Regardless of soffit type, the slots should not exceed 0.63 × 2.5 cm (¼ × 1 in.).

Bats may use an unused or old chimney because the rough surfaces of chimney walls offer suitable places for bats to

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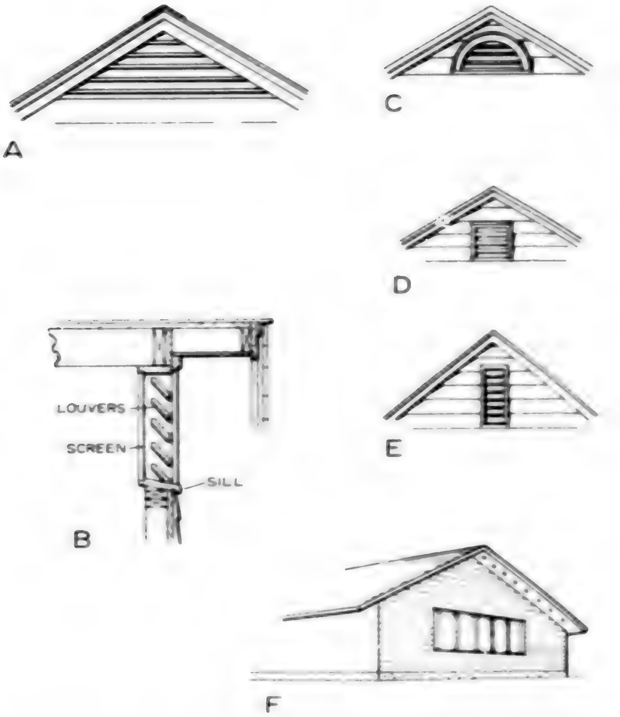

Fig. 14. Ventilators should be properly screened: A. Triangular; B. Cross section; C. Half-circle; D. Square; E. Vertical; F. Soffit. (From Anderson 1970)

hang. To prevent bats from entering chimneys, spark arresters or bird screens should be installed. These should be of rust-resistant material and carefully attached. They should completely enclose the flue discharge area and be securely fastened to the top of the chimney. Except when in use, dampers should be closed.

Insulation

The use of insulation as an effective bat repellent was first reported by Scott (1963) when fiberglass insulation was blown into roof and wall spaces occupied by bats.

To help determine one's eligibility for insulation tax credit, the IRS defines insulation as meaning any item that is specifically and primarily designed to reduce, when installed in or on a dwelling, the heat loss or gain of such dwelling (IRS 1980). To qualify as insulation, the item must be installed between a conditioned area and a non-conditioned area. The term "conditioned area" means an area that has been heated or cooled by conventional or renewable energy source. Insulation includes materials made of fiberglass, rock wool, cellulose, urea-based foam, urethane, vermiculite, perlite, polystyrene, and extruded polystyrene foam.

Insulation materials are manufactured in a number of forms and types. Each has advantages for specific uses. Materials and methods of application are rapidly changing and improving and no one type seems best for all applications. Some basic information was received from insulation experts concerning the possible use of insulation to solve bat management problems (U. S. Department of Energy 1978, 1979).

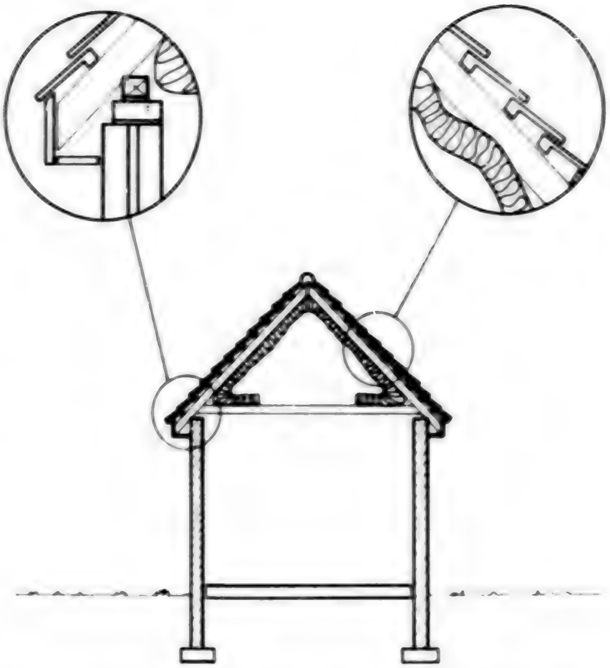

Fig. 15. A properly insulated roof will keep bats out (see Fig. 5). (By J. Newel Lewis, Dip. Arch., F.R.I.B.A. Trinidad and Tobago)

Materials that are inorganic are fire and moisture resistant. The safest appear to be glass fiber (fiberglass) and rock wool. Inorganic insulation is made in batts, blankets, and loose fill and used on attic floors and in frame walls. Organic insulation such as cellulosic fiber is chemically treated to make it resistant to fire, decay, and vermin. Cellulosic fiber, although treated to be fire resistant, may break down in a hot attic (U. S. Department of Housing and Urban Development 1975). Caution should be taken with urea formaldehyde foam insulation, also known as urea-based foam insulation, which may release formaldehyde gas when exposed to heat and humidity (U. S. Consumer Product Safety Commission [CPSC] 1980). CPSC warns that infants, the elderly, and those with allergies and respiratory problems may be particularly sensitive to formaldehyde gas. Once the problem occurs, it can be very difficult and expensive to remedy.

No insulating materials blown into frame walls serve as a barrier to moisture so condensation may become a problem in winter. Wet insulation will not insulate and moisture may collect to cause structural rot. Ventilation paths should not be blocked by insulation (Fig. 15).

Roofing

Spanish or Concrete Tile

An especially difficult challenge has been that of

Fig. 16. Spanish or concrete tile roofing. (Photo courtesy of 3 I Corporation)

excluding bats, particularly the Mexican free-tailed bat, from roosting under Spanish or concrete tile roofing (Fig. 16).

Bats often roost under the tiles by entering the open ends at the lowermost row or where the tiles overlap. The bats enter the openings by landing on or just under the edge that is directly under the open tiles. Where bats enter the sides of the tiles which overlap building walls, they have to land on the wall before crawling inside.

Attempts to prevent the bats from entering the spaces have included plugs made of various materials and shaped to fit the openings. These were ineffective because tight-fitting plugs were impossible to fashion due to variation in size of the openings and temperature changes. Daily temperature fluctuations also caused the tiles to break by contraction and expansion, thus leaving spaces through which the bats could enter.

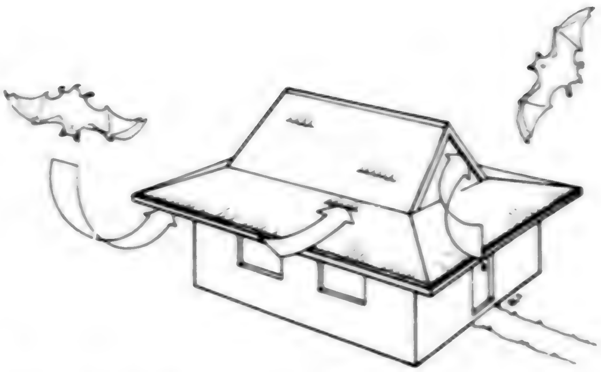

Fig. 17. Gaps under corrugated and galvanized roofing may be sealed with a self-expanding urethane foam, fiberglass, and resin. (By J. Newel Lewis, Dip. Arch., F.R.I.B.A., Trinidad and Tobago)

Constantine (1979*a*) found a solution to the above problem in California when tiles were temporarily removed to replace a layer of tarpaper under the tiles. A layer of coarse fiberglass batting was laid over the tarpaper and under the tiles so that bats entering the holes would contact the fiberglass and be repelled. To prevent birds from using fibers for nest making, the coarse fiberglass batting was applied within 15.2 cm (6 in.) of the outer opening of the open tile ends. Although this solution has been effective, it is only practical to remove the tiles when tarpaper has to be replaced.

Constantine (1979*a*) also found that bats may be excluded from the tiles if rain gutters are installed directly under the open tile ends as well as under the overlapping tiles. The upper edge of the gutter should be level with the lower edge of the tile and should extend outward about 20.3 cm (8 in.) from the tile. The gutter must be tightly fastened flush with the wall to avoid leaving a dark slot that bats may occupy. Another problem occurs when rain gutter installations leave an open space or passage between the gutter and the tiles where bats crawl into the tile openings after landing on the wall. In some instances, flashing material extending upward under the overlapped tiles may be sufficient.

Corrugated and Galvanized

Gaps under corrugated and galvanized roofing and sheeting may be sealed by a self-expanding urethane foam previously mentioned. In Britain, fiberglass and resin have been used in situations where corrugated hanging tiles, roofing, or weatherboarding shift in heating and cooling situations. The fiberglass can be dyed almost any color to match wood or tiles (Fig 17). In some situations, fine mesh, about 0.63-cm (¼-in.) diameter holes, has been spread over

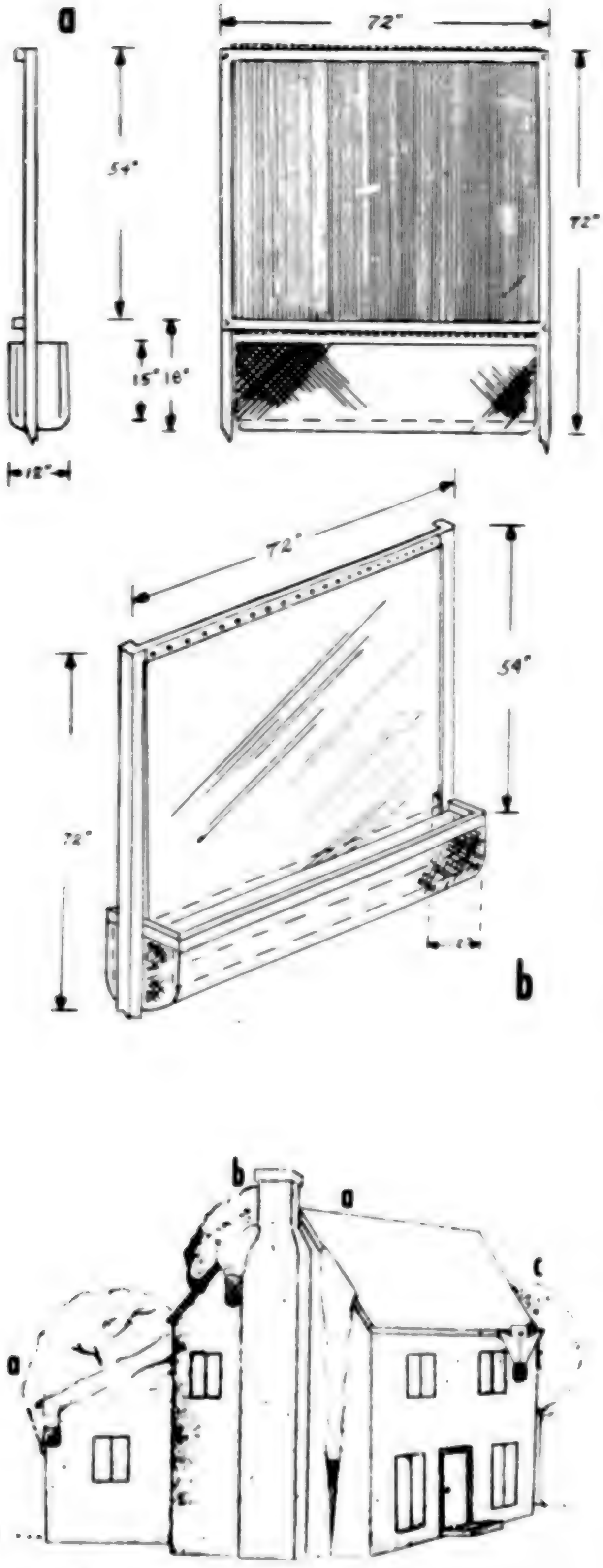

Fig. 18. Types of traps that will collect house bats: top—Constantine harp trap; middle—Constantine plastic trap; bottom—Trap locations on a house. (From Greenhall and Paradiso 1968)

wood or tiles, and then painted to match the underlying material (R. E. Stebbings, personal communication).

Walls

Fiberglass insulation blown into spaces occupied by bats has been reported as an effective repellent (Scott 1963). Newer types of wall insulation such as rock wool may be blown in through holes bored in the wall; however, if urea formaldehyde is used, extreme caution must be exercised as previously discussed. This must not be done while bats are present to prevent their death and decomposition.

Church Steeples

Batproofing of church steeples is difficult and dangerous because the inside of the steeple is often covered with numerous spikes from the roof covering. It is speculated that fiberglass batting over tarpaper could be secured on the inner surface of the steeple or tower to repel bats. The steeple louvers may be covered with 0.63-cm (¼-in.) mesh hardware cloth from the inside and installed so as not to obstruct ventilation.

Temporary Outside Roosts

Sometimes bats will temporarily roost in open structures such as porches, garages, and patios or behind shutters, shingles, roof gutters, and trim with overhang. Transient bats in migration, male bats during the nursing season, and foraging bats hanging up at night to rest may find these outside areas attractive and convenient. If bats roost under the eaves of buildings or on other areas outside the house, actual control may not be necessary unless their droppings become a problem. Then some insulation material will probably work. Constantine (1979*a*) stated that coarse fiberglass batting tacked to the surfaces where bats hang might discourage them. D. G. Constantine stated (personal communication), "It might be worth mentioning that woodpeckers can peck a hole through places like a roof trim to let bats in, too often after exclusion has been performed. I have had to go so far as to recommend covering all trim with sheet metal. Of course, the birds may move down a few inches."

Bat Removal

Live Traps

Although exclusion is the only permanent answer, bats may be trapped alive before batproofing. Griffin (1934) was the first to collect live bats from inside buildings with a "trap roost" attached to the underside of the attic roof ridge where bats often hang. When the bats were disturbed, they retreated into the pockets of the trap instead of into the cracks between the boards of the building. To collect bats as they left buildings, Griffin (1934) devised a variety of traps (tunnel nets and traps, plastic cylinders); their design and use are described by Greenhall and Paradiso (1968; Fig. 18 bottom).

A hopper trap for use around buildings that harbored Mexican free-tailed bats was invented in 1962 by Davis et al. (see Greenhall and Paradiso 1968; Fig. 19). These traps provided storage space for captive bats, so it was possible to set traps in several towns and run them during daylight. The hopper trap is made of black plastic or oilcloth fastened over a wire frame 80 cm (32 in.) high with each side 70 cm (28 in.) at the top and 22.5 cm (9 in.) at the bottom. Below this is suspended a 40-cm (16-in.) deep mesh holding bag, with a drawstring to close each section at the bottom. Another useful feature is a hook attached at each top corner so that, when necessary, several traps may be fastened together like a "nest" to increase the catching area. When using this trap, the size of the exit hole must first be reduced by gluing a slick plastic shield around it. An extra shield must be provided so it will overlap the edge of the trap, which is set at the minimum possible distance below the exit.

An unusual harp-like trap made of steel piano wires was designed by Constantine (1958) to snare large numbers of free-tailed bats (Fig. 18 top). Constantine (1958) also discovered that bats will fly into clear glass or transparent plastic sheets placed vertically at building roost exits (Fig. 18 middle). After striking the obstruction, the bats slide into a smooth-sided container below.

Constantine's trap has undergone numerous modifications. Thin monofilament nylon fishing line may be used instead of steel piano wires. Aluminum tube frames may be used to reduce weight and a double frame of strings improves its effectiveness (Hamilton-Smith 1966). These modifications have been described by Tuttle (1974*a*, 1974*b*) and the efficiency of the trap has been discussed by Kunz and Anthony (1977). Little brown bats were trapped at barn sites by Anthony and Kunz (1977). Tidemann and Woodside (1978) developed a lightweight 7-kg (about 15-lb), collapsible bat trap based on the original designs that can easily be carried and assembled.

A simple, effective bat trap devised by the owners of an old Michigan farmhouse has been described in *The Old House Journal* (Anonymous 1980*a*):

> We bought our 100-year-old farmhouse in the early spring. It was two months later that we discovered bats were living in it too. After trying to get rid of them by scattering moth balls in the attic, which was the only practical solution that anyone suggested, we were relieved when they went into hibernation in the fall. This spring, there were more bat droppings than ever on our window sills. Some had died off in the winter, but there were still about 200 living with us and probably multiplying. We came up with a bat trap which has taken care of the problem. We can now seal up the holes without worrying about the bats finding another exit through the house or rotting inside the walls. The bat trap works on the principle that in order to start flying the bat must first fall out of the hole far enough to spread his wings and begin a glide. We bought a piece (1½ yards) of cheap, sheer curtain material which we sewed into a funnel wide enough at the top to cover the bat-hole and small enough at the bottom to fit over a piece of metal tubing about a foot long (we used a piece of dryer vent). The metal tube is too slippery for the bats to climb up and too narrow for them to fly out. The cloth was securely taped to the pipe and a plastic garbage bag was attached to the other end. We then stapled the top of the funnel to the bat hole at dusk. The cloth should not sag or the bats will catch themselves before entering the pipe and start to climb back up. Then we sat down to watch. The bats fell down the funnel, through the pipe and into the bag . . . . The beauty of this device is that no one touches the bats. After just a few nights, the bat population was nearly exterminated. Our next step was to seal the hole so they would not return. (See Fig. 20)

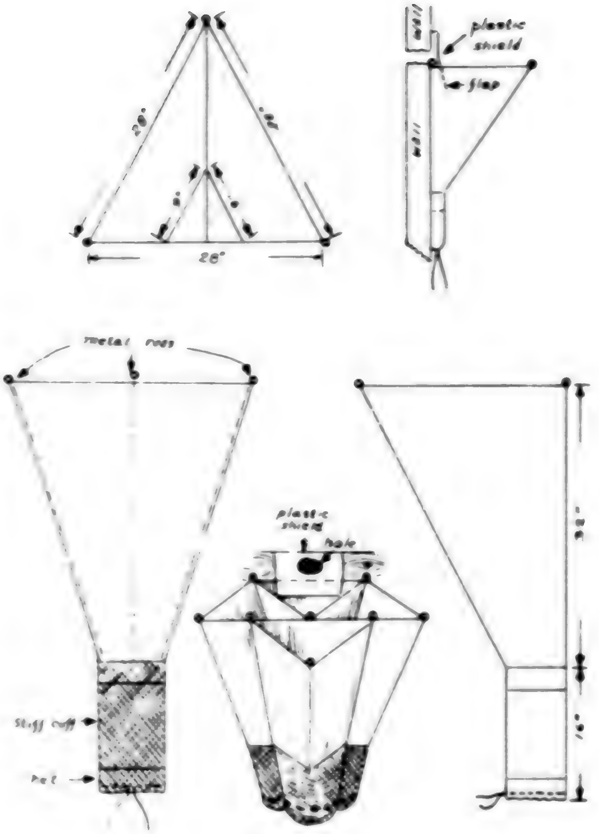

Fig. 19. Details of R. Davis' hopper trap. (From Greenhall and Paradiso 1968)

Traps require little attendance (unless thousands of bats are present) and, after the bats are in the trap bag or container, the animals are protected from weather and most predators. D. G. Constantine (personal communication) cautions that squeaking bats may attract some predators, such as raccoons and cats, which will enter the traps and eat the bats.

Buildings from which bats have been trapped for transplanting must be batproofed to prevent their reentry because bats have strong homing instincts (Davis and Hitchcock 1965; Griffin 1970; Leffler et al. 1979). Live bats should be handled only by rabies-immunized professionals (D. G. Constantine, personal communication).

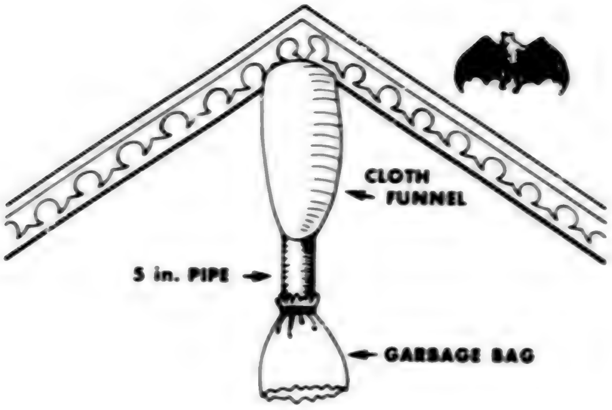

Fig. 20. Effective bat trap (Courtesy "The Old House Journal")

Conservation

Artificial Bat Roosts

If batproofing is effective bats will be displaced and the excluded colony will reestablish in an alternate roost. If none is available will the bats utilize artificial roosts?

Alternate Roosts

The following incident described by Cope (1959) will illustrate the vagaries of batproofing and poses the question of where do dispossessed bats go:

> A friend has been studying the life history of bats and was anxious to set up a breeding colony in the attic of his garage. Because a breeding colony of bats (species not mentioned) in the neighborhood was about to be destroyed, a duplicate of the habitat of this colony was made by my friend: the rafters designed the same, the opening was similar, and some bat guano was even put on the floor. Then about 50 bats were liberated from the established colony into this artificial colony. The bats at first seemed quite at home. They clung to the rafters and found crawl spaces and hideaway places. The bats were liberated in the daytime; the next day not one bat was back at the new location. But in the old location were many bats which had been liberated in the new one. In a week or so, a second roof was built and all cracks and crannies were blocked off so the bats could not get into the house. Then and only then, they were forced to abandon the long-established breeding site. Did they go to the new colony established a short distance from the old site? No. Where they moved, no one knows.

It is known that bats have alternate roosts, which is probably where they go according to D. G. Constantine (personal communication). M. D. Tuttle (personal communication), in agreement, believes that bats require a nearby foraging habitat as well.

Bat Towers

The usefulness of bats as insect feeders and the value of their guano led to several attempts to encourage Mexican free-tailed bats to occupy artificial bat towers (Greenhall and Paradiso 1968: Fig. 3). Campbell (1925) spent his life working on such a structure. He built a tower but the bats living in an old hunting lodge a few miles away refused to move into the tower. Campbell reasoned that the bats depended on their delicate sense of hearing and perhaps some sounds would have a repellent effect. A brass band with cornets, clarinets, piccolos, saxophones, trombones, drums, and cymbals, provided a variety of noises. Finally, Campbell found that the only music the bats could not stand was the waltz, "Cascade of Roses," as played by the Mexico City Police Band. He wrote: "With the sound of the very first measures, a great uneasiness and shifting of the bats was observed, but with the first fortissimo, they began leaving; first in singles, then pairs, then tens and hundreds in one continual stream, until they had all left. Their time of emergence in that month, August, was always about 6:30 o'clock; now they left one and a half hours before their accustomed time." The bats moved into the tower and during the following 6 years, never returned to their old home. The strategy was successfully repeated when a clergyman wished to get rid of some bats lodging in his room. Having heard of the "concert" experiment, he purchased a phonograph, a few records, and won the battle in 1 day.

The fact that the artificial roost was satisfactory warrants further study. R. A. Raschig, inspired by Campbell's efforts, built a bat tower in Eagle River, Wisconsin, which attracted bats (personal communication). In the fall of 1979 a woman "saw bats come out of the roost by the hundreds. I have not seen a permanent colony but have reason to believe that the bats use this roost as a stopping off place in their migrations in the spring and fall. At times there are hawks and owls roosting on top of the bat roost presumably waiting to get a dinner when the bats emerge."

Bat Houses or Boxes

During the past 50 years the natural holes in trees have been reduced in numbers by removal of dead and dying trees which provided cavities for many animals, including bats. In Europe bird boxes have been used for about a century. Since the late 1930's, European bat biologists have provided a variety of boxes and houses for bats. The success of these artificial bat roosts has encouraged English and American investigators to experiment further (Fig. 17). The English bat biologist, Stebbings (1974), stated that "Although insufficient knowledge is known about the critical roost requirements of bats, they can be attracted to roosting boxes attached to trees. These boxes simulate tree holes (like bird boxes) and can be used by large numbers of bats of most species. One box of about 10 cm cube can hold up to 50 bats." Krzanowski (1955) has had excellent results with bat boxes in Poland.

Since the use of bat houses or boxes is new in the United States there is much to be learned. The two models (Fig. 21) have been used successfully in Europe. Suggestions for building bat houses and attracting bats are provided by

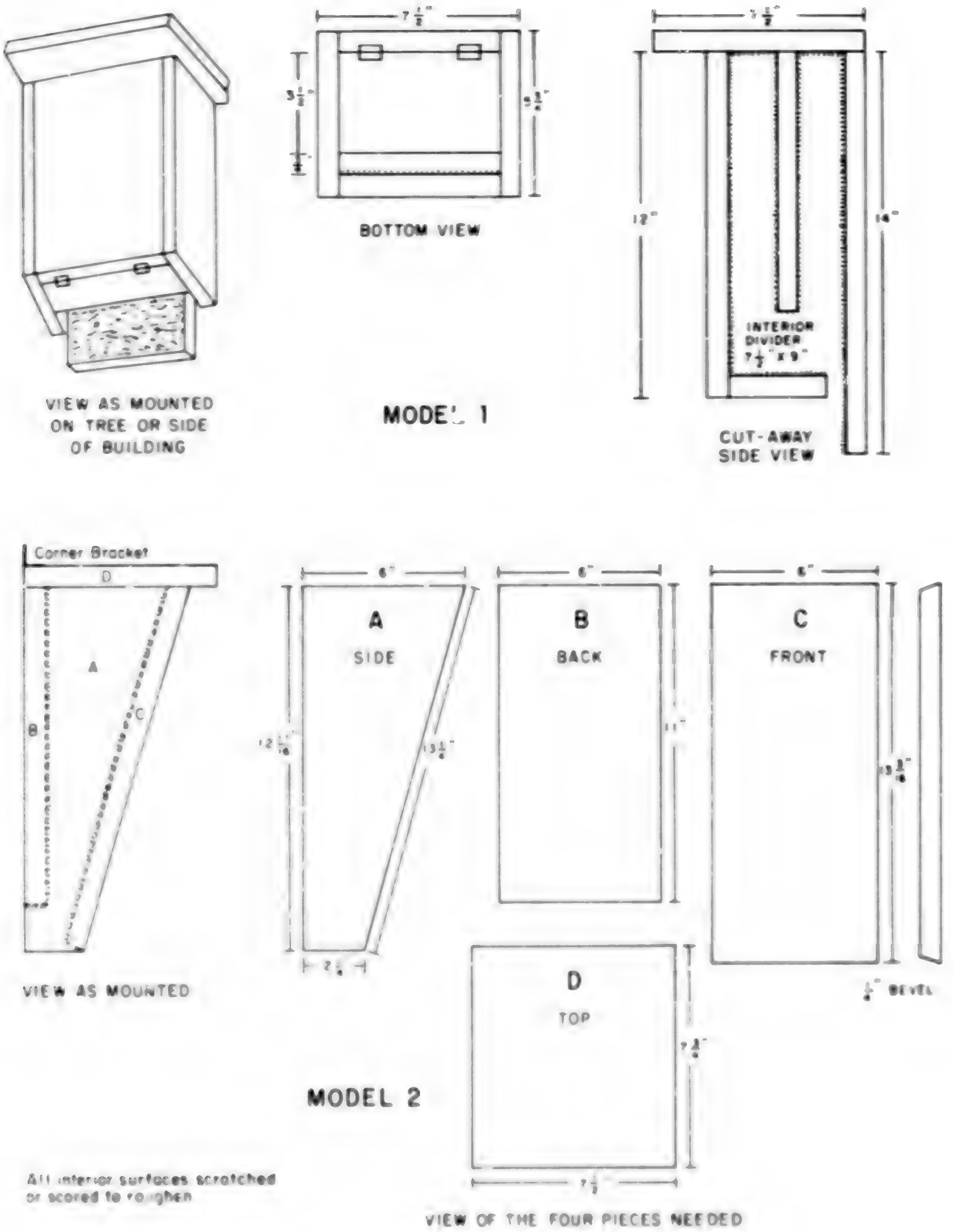

Fig. 21. European bat houses (Courtesy of Merlin D. Tuttle)

Tuttle (n. d.). Size and shape do not appear important but the width of the entry space should not exceed 2.5 cm (1 in.). All inner surfaces must be roughened so that the bats can easily climb. Because inside house temperatures should not exceed 32 C (90 F) the box should be insulated by covering the top and sides with tarpaper, styrofoam, or even painted black to absorb the heat from the sun and provide a suitable temperature at night, especially for a maternity colony. Bat houses should be securely fastened to the side of a building or tree trunk 3-5 m (12-15 ft) above the ground and protected against birds and squirrels.

Food supplies must be adequate and bat boxes should be located near some water where insect populations are abundant. Sometimes a bat house may be occupied within weeks after it is erected, preferably by early April, or it may take a year or more for bats to find, approve, and move into a bat house. A well-insulated box located near water, securely fastened, and protected against wind, predators, and direct sunlight increases the chances of early occupancy.

The Missouri Department of Conservation reported that some private citizens designed and built a large structure called a "bat refuge" (Fig. 22) that was attractive to little brown bats and quickly occupied (LaVal and LaVal 1980). This artificial bat roost is located at Tea Lakes Wildlife Area, near Rosebud, Gasconade County. It was erected during the spring of 1979 and was used later by a maternity colony of at least 78 little brown bats during the summer of 1979. The colony originally occupied a picnic shelter close to where the artificial roost was built (note the picnic shelter in the background of the photograph). The picnic shelter caretaker gradually stopped up holes and cracks to encourage the bats to move. It is not known why the bats moved but it is believed that they were possibly attracted to the refuge by spraying it with a guano solution. R. K. LaVal (personal communication) suggested that the roost (Fig. 23) be modified by reducing the spaces at the bottom between the dividers to less than 2.5 cm (1 in.), making slit openings into the air space under the roof which should make the roost more suitable for maternity use by the bats, and by raising the structure to reduce disturbance from people, dogs, and other organisms.

Plans based on this successful but experimental bat house were developed by the Missouri Department of Conservation (G. T. Maupin, personal communication). The Department is currently implementing plans to design, build, and field test additional bat refuge structures, to be able to offer a viable alternative to the extermination or exclusion problem of bats in buildings (LaVal and LaVal 1980).

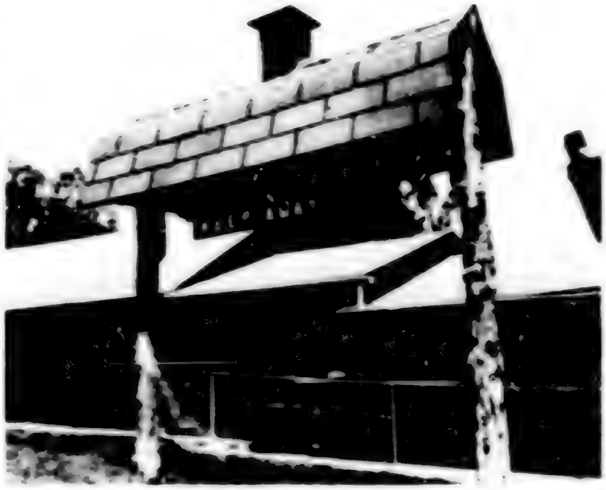

Fig. 22. Artificial bat roost built by private citizens at Tea Lakes Wildlife Area near Rosebud, Missouri. (Photo by Richard K. LaVal)

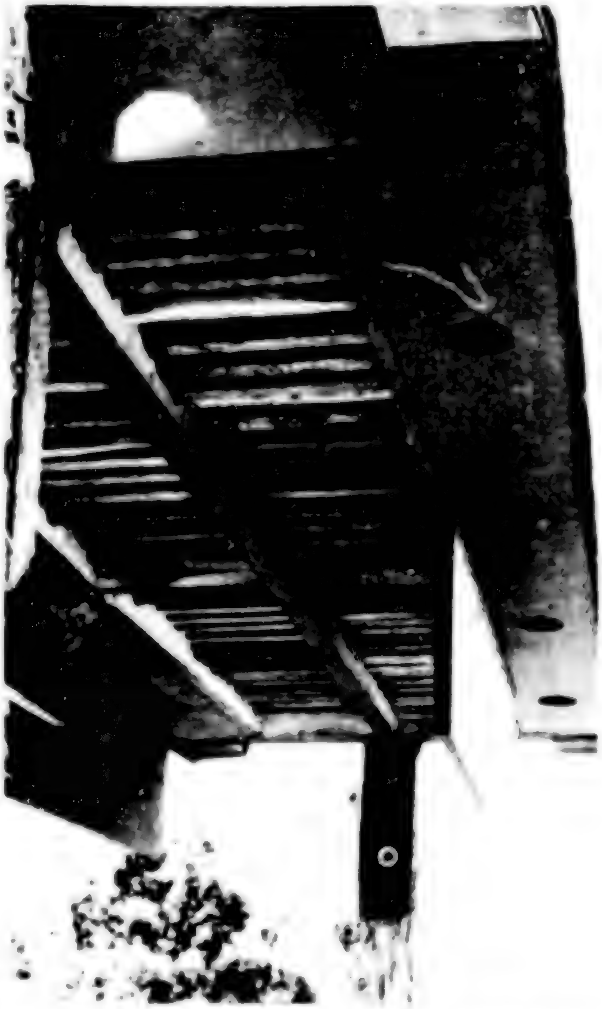

Fig. 23. Artificial bat refuge (bottom) at Tea Lakes Wildlife Area near Rosebud, Missouri. (Photo by Richard K. LaVal)

Discussion and Recommendations

Bat Management Problems

Excluding bats from buildings by nonlethal methods is not new (Silver 1935) but its actual use has not been widespread. Most published studies have involved only brief applications and short-term results with little information to support claims of efficacy and safety. The use of pesticides dramatically increased after World War II and appeared to be the ultimate tool. Batproofing by nonlethal means was deemphasized. During the past 30 years, however, there have been rising anxieties concerning the environment and health hazards caused by chemicals.

Bat Conservation

The concern for bat protection began in the late 1960's when dramatic declines of once plentiful species were observed. For example, Carlsbad Caverns' millions of Mexican free-tailed bats declined to less than one-half million during the 1970's. This concern for the preservation of wildlife generated the passage of recommendations and

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resolutions proposed by organizations such as the World Health Organization, National Academy of Science, and many others. These groups cited a variety of reasons for the decline in populations which have been discussed earlier. Recommendations included (1) protective legislation; (2) regulation of research; (3) prohibition of chemicals which not only exacerbate the situation but further contaminate the environment; and (4) education of the general public on the reasons for bat conservation which impinge on house bat management.

Bats are often killed because they live near people who needlessly fear them and Tuttle (1979*b*) stated, "Their decline certainly is not in our best interests."

Bat Management in Cities and Suburbs

The Committee on Urban Pest Management of the National Research Council (1980) recognized that bats can be a serious urban and suburban problem. Previously attention was focused on the solution of nuisance problems and public health hazards. Integrated pest management is the suggested approach. This is based on the principles of applied ecology and a knowledge of the ecosystem. Integrated programs usually evolve slowly. Urban and suburban planners and others concerned about future research are referred to Leedy et al. (1978). Those charged with the responsibility for urban pest management decision making are referred to "Urban Pest Management," a report prepared by the Committee on Urban Pest Management (National Research Council 1980).

Research Needs

Research proposals should carefully explore, quantify, and evaluate all possible methods, materials, and costs when applying for grants (White 1975). Throughout this manual, emphasis has been placed on batproofing and the use of nonlethal methods and materials for house bat management. There are many questions still to be answered. What are the factors that govern roost selection? Where do bats go when they are dislocated and excluded from buildings? Why do bats prefer one structure to another, although both structures appear similar in all respects? Are artificial roosts a useful house bat management technique? A nonlethal chemical repellent that could safely and rapidly flush bats from buildings and then quickly dissipate without any residue would be useful. Additional studies are appropriate concerning retrofit of buildings, bat pheromones (animal communication odors), bat vocalizations, and other factors. New techniques and instrumentation, as well as adaptions of existing methods and materials, should be devised so that quantification of results is possible. Laser beams attached to electronic counters (Fenton et al. 1973); telemetry (Kolz and Corner 1975); bat detectors (Anonymous 1978), sonar, radar, and chemiluminescent tags (Buchler 1976) are useful to track bats that have been excluded from a roost and may be searching for an alternate roost. Movements of bats in and out of roosts can be monitored with electronic counters; R. E. Stebbings (personal communication) stated, "I have used automatic timed counters for 12 years. They record date, time, direction of movement, etc. all automatically."

Bat Management Legislation

Federal

A survey of Federal legislative actions, court decisions, and agency interpretations concerning the management of bats was published in "Bat management in the United States" (Lera and Fortune 1978); the agencies having primary responsibilties for bat management decisions are the Department of the Interior, the Environmental Protection Agency, and the Department of Health and Human Services (formerly the Department of Health, Education, and Welfare). It is apparent that lethal control of bats, even when there is a proven potential danger to humans, is subjected to careful scrutiny, preparation, and interagency coordination.

The United States Department of the Interior is the Nation's principal conservation agency. The FWS has broad responsibilities for wildlife conservation as mandated in various Executive orders, laws, and treaties. It has direct responsibility for bat research, protection, and management under the Fish and Wildlife Coordination Act of 1956 and the Endangered Species Act of 1973.

Because FWS policy prohibits the use of DDT and recommends against the use of anticoagulants or other chemicals that may present a threat to human health or the environment, the major management recommendation is exclusion of bats (batproofing). The only acceptable way that the FWS can manage bats in buildings and carry out its responsibilities of bat protection and conservation is to exclude unwanted bats by nonlethal methods. Bat management techniques should be selective for the offending bats, nonhazardous to human beings, and environmentally safe.

State

Table 2 provides a summary of States and territories of the United States with laws or regulations applying to bats, and the agency within the State that governs the laws. Information applies from 1972 to present. Some States have laws specifically mentioning bats, either providing or denying protection. Others have legislation that applies to bats only by interpretation. Bats may be considered to be non-game wildlife or indigenous State mammals. Nonspecific legislation depends on the interpretation. Some States offer protection for bats but the laws appear to be designed in the interest of public health, addressing bats as vectors of disease rather than as mammals needing protection. Some States do not have legislation but anticipate developing bat protection legislation following increases in nongame wildlife funding, public interest, or bat research. Some species have protection through endangered species laws as either Federal- or State-listed endangered species, but the same State may offer no protection for other

Table 2. *A summary of State bat legislation.*[a] *(From Convoy 1980)*

States	Cave	Endangered species	Hunting	Collection	Natural Resources	Conser-vation	Habitat access	State land	Public health	Pesticide board
Alabama		F			P I	P/I	P			
Alaska			NP S	I				P I		
Arizona	P		NP S	I						
Arkansas		F	P I	I						
California			P I	I					L	
Colorado			P S	I					L	
Connecticut		F								L
Delaware									L	
District of Columbia									L	
Florida		F								
Georgia	P	F								
Guam		A	P S	S						
Hawaii		ST			P S					
Idaho		NP I								
Illinois		F				A				L
Indiana		ST			P S					
Iowa		ST	NP I				A			L
Kansas	P									
Kentucky		ST								
Louisana		F	NP I	I						
Maine		A	P I	I						L
Maryland	P	F ST			A			P I		
Massachusetts		F	P I				P	P		L
Michigan		F		I						L
Mississippi			NP I							
Minnesota		P		I						
Missouri	A	F		I		P S	P			
Montana		A					P			
Nebraska			NP I	I						
Nevada										
New Hampshire		A	NP I							I
New Jersey		F	P I						I	
New Mexico		ST	A							
New York		F	NP I						L	I
North Carolina		F	P I	I		A				I
North Dakota			NP I							
Ohio		ST			P I					
Oklahoma	P									
Oregon									I	
Pennsylvania		F	NP I							
Puerto Rico	A									
Rhode Island										
South Carolina		F	NP I							
South Dakota			P I	I						
Tennessee	A	F	P I	I			P			
Utah					P I					
Vermont		A	NP I				A			
Virginia		F								
Washington			P A							
West Virginia	P		P I	I						
Wisconsin		I								
Wyoming			NP S							

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[a] P = protected; NP = not protected; L = laws for bats, F = federally endangered species, A = anticipated protection; I = bats by interpretation; S = bats mentioned; ST = State endangered species

species of bats. Without enforcement or public awareness programs, legislation may not actually accomplish the goal of protecting bats. The listing in Table 2 should not be considered complete or entirely accurate due to lack of response by some State agencies or interim changes in legislation.

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Appendix A

Identification Key to Bats Most Encountered by Humans in Houses

Use of Key

As a tentative means of identifying animals, keys have been devised that use arbitrary, selected characteristics that should be readily distinguishable. However, keys are extremely fallible, and specimens are not always easily identifiable. To use the key, start at number 1 on the left side of the page. There will be two contrasting statements. Select the one that best fits your bat. Then refer to the number or name at the right side of the page. If it is a number, look for this number on the left; again there will be two statements. Proceed as before remembering that it is important to consider each of the two alternatives; one should fit the bat in hand and lead to another pair of alternatives or the name of the bat. The figure that refers to a number should assist in making your decision. The figure that refers to a name should reasonably resemble the specimen to be identified. If it does not, try again. It is easy to select the wrong alternative at some point and the identification will then be erroneous. If you cannot identify the bat it may be necessary to send it to the nearest museum, zoo, or public health laboratory.

Identification Key

1. About half the tail extends beyond tail membrane; face bare; lips wrinkled; ears close together at base but not joined (Fig. 26) .... *Tadarida brasiliensis*

2. Tail completely enclosed within tail membrane; face furred; lips not wrinkled; ears widely separated (Fig. 25) 3

3. Ears large, projecting upward, 28 mm (1.1 in.) from base to tip; nose pugged or pig-like (Fig. 28) .... *Antrozous pallidus*

Ears not large, do not project upward, less than 25 mm (1 in.) from base to tip; nose not pugged or pig-like 4

4. Tail membrane upper surface well furred, at least front half, hair tips or hair usually silver-tipped (Figs. 29, 31) 5

Tail membrane upper surface naked or sparsely furred, hair tips or hair not silver-tipped (Figs. 2, 25) 7

5. Hair black (Fig. 29) .... *Lasionycteris noctivagans*

Hair red orange, yellowish 6

6. Ears conspicuously black-edged with patches of yellow hair inside (Fig. 31) *Lasiurus cinereus*

Ears not black-edged, inside bare or scant-haired (Fig. 30) .... *Lasiurus borealis*

7. Size large; wingspread 325 to 350 mm (13 to 14 in.) (Fig. 25) .... *Eptesicus fuscus*

Size small; wingspread 220 to 270 mm (8.8 to 10.8 in.) 8

8. Fur on back glossy; hairs on toes long and conspicuous (Fig. 24) ..... *Myotis lucifugus*

Fur on back dull; hairs on toes sparse and inconspicuous (Fig. 27) ... *Myotis yumanensis*

Appendix B

Species Accounts

Myotis lucifugus**.** Little brown bat, common bat, cave bat, little brown myotis.

Wingspread: 222 to 269 mm (8.9 to 10.8 in.).

Forearm: 34 to 41 mm (1.3 to 1.6 in.).

Recognition: Fur is dense, fine, and glossy. Both sexes a rich brown, almost bronze; juveniles may be almost black. Ears and membranes are a glossy dark brown. There are many small brown species but this is the one most often found in buildings (Fig. 24).

Distribution: From Labrador to southern Alaska, the mountains of southern California, as well as from the Appalachians to Georgia and west into Arkansas. Stragglers can be found in New Mexico, Texas, Mississippi, and Alabama, and the coastal parts of the Carolinas.

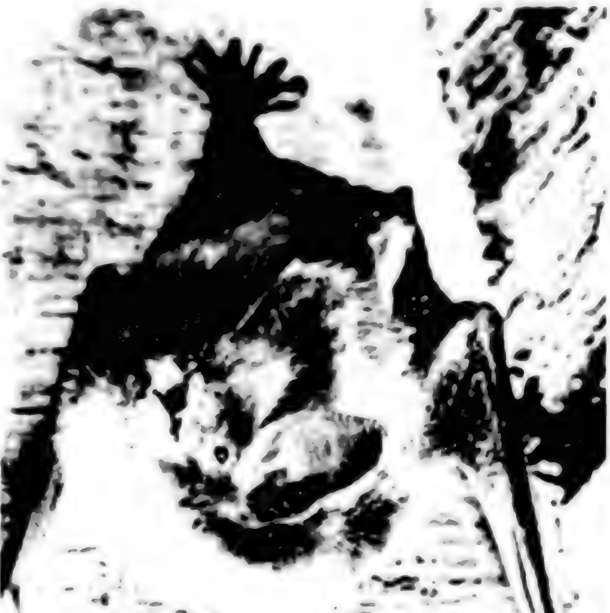

Fig. 24. Little brown bat, *Myotis lucifugus*. (Photo from Barbour and Davis 1969)

Comments: One of the most abundant of all colonial bats in the northern part of its range; is common within its range. In the spring and summer females form maternity colonies of hundreds of individuals or more in attics, barns, and other retreats that are dark and hot during the daytime. In winter, these bats hibernate in caves and mines, frequently returning year after year to the same nursery colony and hibernation cave. Colonies are far more common near lakes and rivers. Rabies is seldom a problem with this species since it is not an effective biter due to its small teeth.

Eptesicus fuscus**.** Big brown bat, house bat, barn bat, dusky bat.

Wingspread: 325 to 350 mm (13 to 14 in.).

Forearm: 42 to 51 mm (1.7 to 2.0 in.).

Recognition: Probably the largest bat commonly found in buildings except for the pallid bat. Most adults are copper-colored, but color may vary from light to dark brown. Each hair is bicolored — the basal half being almost black and the outer half brown. Face, ears, and membranes are dark brown to nearly black. Sexes are colored alike and show no seasonal variation (Fig. 25).

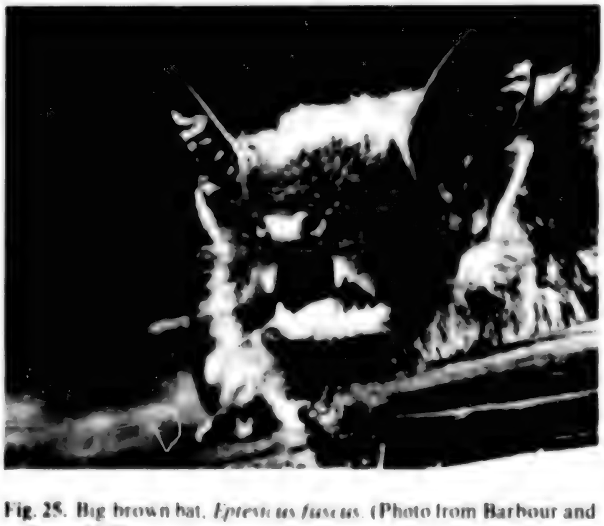

Fig. 25. Big brown bat, *Eptesicus fuscus*. (Photo from Barbour and Davis 1969)

Distribution: From Alaska and southern Canada south through New England to Florida, extending coast to coast. It is abundant throughout most of its range, except in the far northern States and the deep South. Apparently unknown from southern Florida and much of central Texas.

Comments: The big brown bat is probably the colonial bat most familiar to man. In summer, it commonly roosts in attics, belfries, and barns; behind awnings, doors, and shutters; but seldom in caves. It is a hardy species that can endure subfreezing temperatures but is not as tolerant of high temperatures as is the little brown bat. During hot weather, it may crawl into rooms from crevices of fireplaces, or both young and adults may appear in basements if the space between the inside and outside walls is continuous from attic to basement. Colonies vary in size between 12 and 200. They have a remarkable homing instinct and do not migrate far from their place of birth. They are one of the last bats to hibernate in fall and first to arouse in spring, and may be seen flying about at dusk in late November and early March, spending the winter in buildings, caves, mines, and similar shelters. *Eptesicus* is easily recognizable due to its large size and steady, straight flight at a height of 6.1 to 9.1 m (20 to 30 ft) or more. After feeding, the bat flies to a night roost to rest, favoring porches, brick houses, garages with open doors, or a breezeway. The tell-tale signs of its presence are a few droppings left each morning below the roost. Big brown bats can inflict a painful bite if carelessly handled. This is one of the species most often rabid.

Tadarida brasiliensis. Mexican free-tailed bat, free-tailed tailed bat, guano bat.

Wingspread: 290 to 325 mm (11.3 to 13 in.)

Forearm: 36 to 46 mm (1.4 to 1.8 in.).

Recognition: A rather small bat with long narrow wings, and about one-half of the tail extending beyond the interfemoral membrane. The ears almost meet at the midline but are not joined and have a series of papillae or wartlike structures on the anterior rims. The upper lips are wrinkled. It is the smallest of the free-tailed bats in the United States. The body and membranes are dark brown. Individuals are dark gray or pale brown due to bleaching by ammonia fumes from guano deposits (Fig. 26).

Distribution: Found from California to Florida, migrating into Texas and Mexico. Occasionally found as far north as Oregon, Nevada, Utah, and in the East as far north as North Carolina.

Comments: This species is the most colonial of all bats. The habitat of the free-tailed bat differs in various parts of the United States. It inhabits buildings on the West Coast and in the Southeast. It is primarily a cave bat in Arizona, New Mexico, Oklahoma, and Texas. Maternity colonies of 1,000 or more may inhabit a single building in California. In Florida, the species never enters caves and thousands have been found in a single building. Jennings (1958), cited by Barbour and Davis (1969), wrote that in Florida nearly every town harbors one or more colonies of free-tailed bats, yet the Department of Health and Rehabilitative Services stated, "We receive few complaints of bats in buildings . . . ." (F. L. Hoff, personal communication). In Texas, Davis (1962), cited by Greenhall and Paradiso (1968), stated that "throughout south Texas every group of a dozen or more buildings is likely to have at least one guano bat roost for some period during the year." An estimate was given of 3 roosts per 1,000 human population, each having over 100 bats. Texas has a house bat problem according to officials. In Texas it is also a cave bat and Davis et al. (1962) estimated that the total population in caves in 1957 was at least 100 million. At Carlsbad Caverns, New Mexico, the population has been estimated from as high as almost 9 million in June 1936 (Allen 1962) to a low of 0.25 million (Edgerton 1966; Petit 1978) due to pesticide poisoning. *Tadarida brasiliensis* has been found positive for rabies. No one should enter a cave containing thousands of bats unless immunized against rabies. It is thought that two human fatalities from rabies in a Texas cave resulted from airborne exposure attributed to this species.

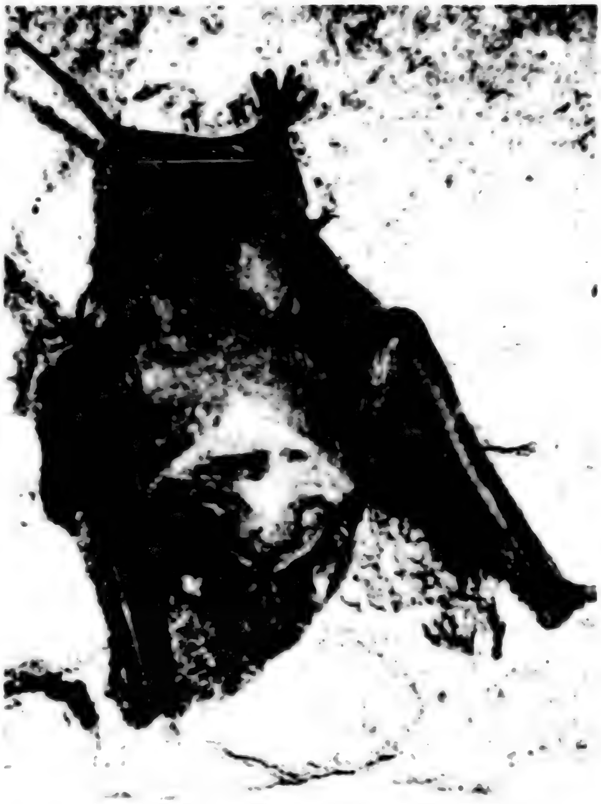

Fig. 26. Mexican free-tailed bat, *Tadarida brasiliensis*. (Photo from Barbour and Davis 1969)

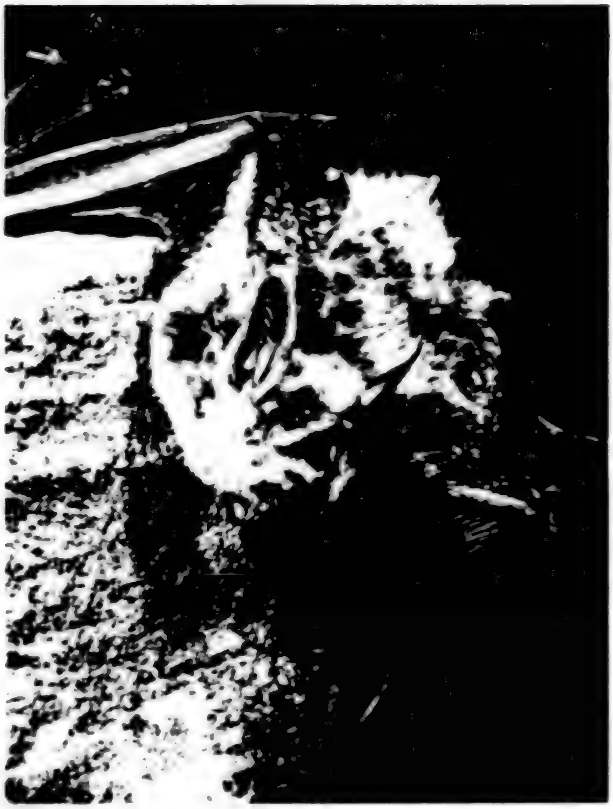

Fig. 27. Yuma myotis, *Myotis yumanensis*. (Photo from Barbour and Davis 1969)

***Myotis yumanensis*.** Yuma myotis

Wingspread: About 235 mm (8.7 in.)

Forearm: 32 to 38 mm (1.3 to 1.5 in.)

Recognition: Light tan to dark brown, the underparts whitish to buffy. The membranes are darker than the body (Fig. 27).

Distribution: Found in western North America from Canada to Mexico.

Comments: More closely associated with water than any other bat except the gray bat (*Myotis grisescens*). In North America, it is always found near open water. A nuisance in California where large nursery colonies may be found in buildings, attics, porches, and abandoned cabins. A colony of about 5,000 inhabited a church belfry in Nevada and some transients were found in the ventilators of a building in Berkeley, California (Barbour and Davis (1969). It has been found rabid but rarely is a hazard to humans.

***Antrozous pallidus*.** Pallid bat, desert pallid bat

Wingspread: 360 to 390 mm (13 to 14 in.)

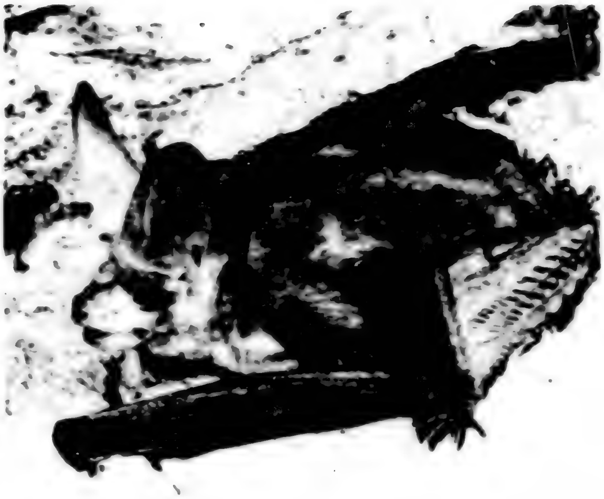

Fig. 28. Pallid bat, *Antrozous pallidus*. (Photo from Barbour and Davis 1969)

Forearm: 48 to 60 mm (1.9 to 2.4 in.).

Recognition: Light yellow above the hairs tipped with brown or gray, whereas the underparts are pale creamy, almost white, but not bicolored. Membranes are tan. This is a large bat with big ears, large eyes, and broad wings. The pig-like snout is distinctive (Fig. 28).

Distribution: Found primarily in the western United States from the Pacific Northwest to the Southwest.

Comments: This colonial species is occasionally troublesome in California where the same open shelter (readily accessible by flight) serves as both day and night roost. The bats hang from the rafters and their droppings foul hay in barns and cars in garages. This species has one of the most unique feeding habits of any North American bat. Prey is mainly from the ground and little, if any, food is captured in flight. Food consists of scorpions, grasshoppers, Jerusalem crickets, June beetles, and other ground beetles. It is a relatively slow flier, foraging close 0.9 to 1.2 m (3 to 4 ft) to the ground. It has been found rabid but is rarely a problem to humans.

***Lasionycteris noctivagans*.** Silver-haired bat, silvery black bat, black bat

Wingspread: 270 to 310 mm (10.5 to 12.1 in.)

Forearm: 37 to 44 mm (1.5 to 1.8 in.)

Recognition: The fur is long and soft. The hairs are strongly tipped with silvery white which produces a frosted appearance on both sexes. The back and sides are blackish brown. The membranes are blackish. The tail or interfemoral membrane is lightly furred only on the basal half close to the body on the upper surface (Fig. 29).

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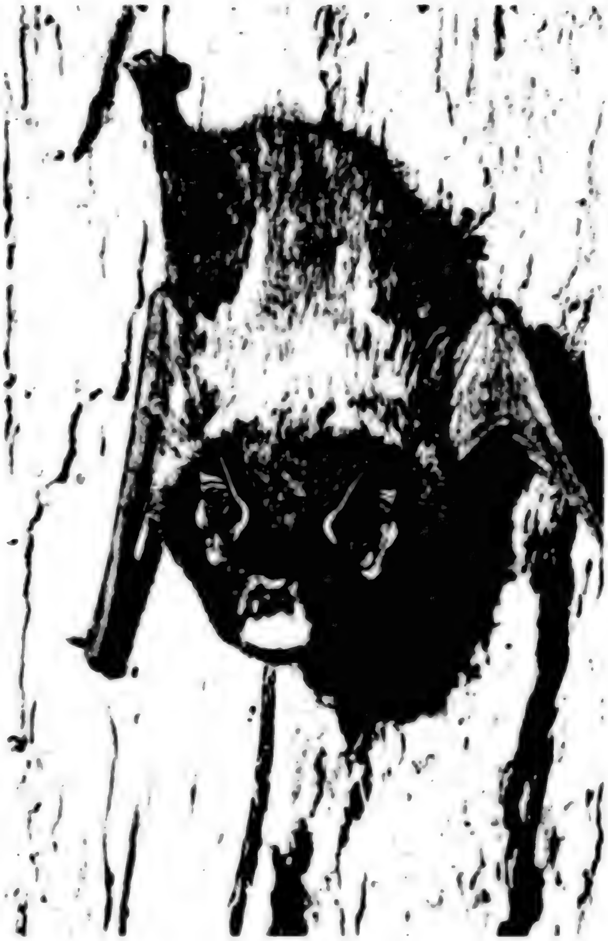

Fig. 29. Silver-haired bat, *Lasionycteris noctivagans*. Note hairs of back tipped with white. (Photo from Barbour and Davis 1969)

Distribution: All over northern North America.

Comments: This medium-sized bat is smaller than the big brown bat and larger than any of the myotis. It is one of the species most often involved in causing rabies in humans. Exposure is almost entirely the result of careless handling of individual sick bats that are found on the ground or on the sides of buildings.

Lasiurus borealis. Red bat, leaf bat, tree bat, northern bat, New York bat.

Wingspread: 290 to 332 mm (11.6 to 13.3 in.)

Forearm: 35 to 45 mm (1.4 to 1.8 in.)

Recognition: This solitary medium-sized bat is easily distinguished by its bright rusty color, short rounded ears and long pointed wings. The interfemoral membrane is thickly furred on the entire upper surface. The underparts are paler than the back, and hairs lack much of the white tipping. There is usually a white shoulder spot. Males tend to be redder and less frosted than the females (Fig. 30).

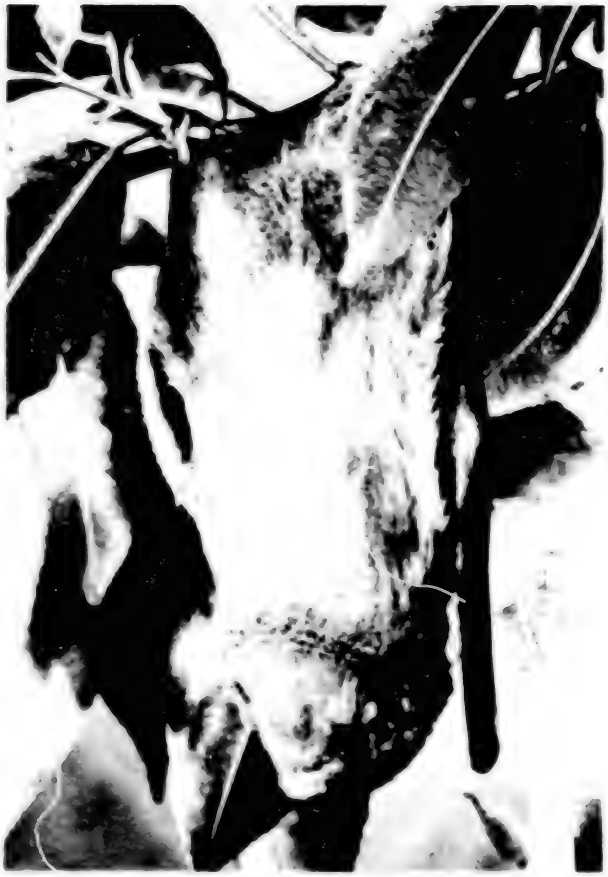

Fig. 30. Red bat, *Lasiurus borealis* hanging by both legs. The heavily furred interfemoral membrane is extended. Note short rounded ears. (Photo from Barbour and Davis 1969)

Distribution: All over North America.

Comments: This solitary bat extends its long tail membrane straight out in flight. It only occasionally enters buildings during migration and seems to have well-developed flyways which it follows annually. Unlike other bats, copulation begins while the bats are in flight and sometimes ends on the ground where they may be encountered. Red bats produce larger litters (up to five individuals) than other species of bats. They are rarely encountered by humans except when sick, which explains the high incidence of rabies in those sampled.

Lasiurus cinereus. Hoary bat, frosted bat, great northern bat, twilight bat.

Wingspread: 380 to 410 mm (15.2 to 16.4 in.)

Forearm: 46 to 58 mm (1.8 to 2.3 in.)

Recognition: This solitary bat is one of the largest in North

America, larger than the big brown bat. It is dark-colored and heavily furred. The tips of many hairs are white, giving an overall frosted, hoary appearance. The ears are relatively short and edged with black. Usually there is a white shoulder spot. The membranes are brownish. The upper surface of the interfemoral or tail membrane is completely furred. The much smaller silver-haired bat (which lacks fur on the feet, ears, and underside of the wings) is the only other bat that could be confused with the hoary bat. The upper basal surface of the tail membrane is lightly furred (Fig. 31).

Distribution: *Lasiurus cinereus* is the most widely distributed of all U. S. bats, probably occurring in all 50 States—although not yet reported from Alaska. A smaller, more reddish race, the Hawaiian hoary bat *(L. semotus)*, is restricted to the Hawaiian Islands and is on the Endangered Species List.

Comments: It is exceeded in size only by the largest free-tailed bats. Rabid individuals are occasionally found except on the Hawaiian Islands. Its habits seldom bring it into direct contact with man, but because of its exceptionally large teeth it is an effective biter and potential transmitter of rabies if carelessly handled.

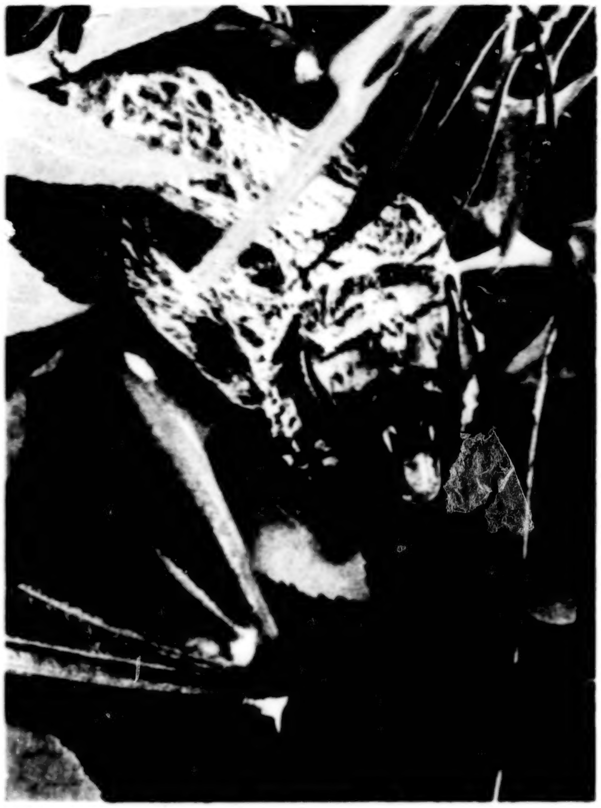

Fig. 31. Hoary bat, *Lasiurus cinereus*. Defensive pose. Note silver-tipped hair and black-edged ears. (Photos from Barbour and Davis 1969)

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